

The University of Chicago

STUDIES ON THE ECOLOGICAL RELATIONS
OF BEES IN THE CHICAGO REGION

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF ZÖOLOGY

1932

By
JAY FREDERICK WESLEY PEARSON

Private Edition, Distributed by
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CHICAGO, ILLINOIS

Reprinted from
ECOLOGICAL MONOGRAPHS
Vol. III, No. 3, 1933

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STUDIES ON THE ECOLOGICAL RELATIONS OF BEES IN THE CHICAGO REGION

I. INTRODUCTION

The data reported in this work were accumulated as part of a program involving the eventual development of a detailed knowledge of the ecology and taxonomy of the American species of bees.¹ The attempt has been made to become acquainted with a majority of the species found within a radius of seventy-five miles of Chicago and to determine whether these species show a general adaptation to certain regions possessing various combinations of physical conditions which may be described as plant communities, and whether such adaptations, if they exist, can be demonstrated experimentally.

Cowles (1901) and his followers (Fuller 1914, 1925; etc.) have worked out the plant communities of the Chicago area and have made various studies of the physical conditions prevailing in these communities and responsible for them. Shelford in "Animal Communities of Temperate America" (1913) and more recently Holmquist (1926) and Park (1930) have studied certain animals living in these areas and have found that they form communities which, in many cases, correspond remarkably well with the plant communities not only in geographical distribution but also in succession. These workers with animal species have also devoted much time to the study and measurement of the physical factors which may be considered as exerting a limiting or controlling effect upon the distribution of the animal species, but they have by no means overlooked direct influences exerted by the plants themselves in setting up the bounds of occurrence, or possibly we should say degree of abundance, of any given species or group of animals.

Land studies have been mostly concerned with such factors as light (Park, 1930), heat, evaporation-rate and humidity (Fuller, 1914). Among all publications reporting comparative studies in the distribution of animal groups among neighboring plant communities having quite different biotic and physical make-ups, the writer is unaware of any dealing with bees, aside from some references by Cockerell (1893) to vertical distribution of bee species in a mountainous locality in Colorado, and the recent work of Graenicher (1930) dealing with bees and plant communities in the Miami, Florida, region. Shelford (1913) includes long lists of animal species taken in various communities but mentions very few species of bees.

The omission of this large group of insects from studies hitherto made can be explained but is surprising. Bees are not rare in the Chicago region,

¹ Essential portions of thesis accepted by Department of Zoölogy, University of Chicago. Acknowledgment is made of the advice and assistance of Dr. W. C. Allee, Dr. A. E. Emerson, and Dr. G. D. Fuller, of the University of Chicago, of Dr. Charles Robertson, of Carlinville, Illinois, and of Dr. T. H. Frison, of the Illinois State Natural History Survey.

nor in any region in the United States. Graenicher's list reveals Southern Florida as possessing one of the poorest of bee faunas. He gives 65 species. Viereck (1916) gives 171 species taken from Connecticut and a total of 234 to be expected there. Leonard in "Insects of New York" (1926) gives 189 species; Graenicher (1911) gives 166 species collected during two trips into Northern Wisconsin; while Robertson (1928) reports 297 species from the Carlinville, Illinois, region. The present work includes 169 named species while a considerable number await final identification or description. Any collecting for general insects made during spring, summer, or early fall, reveals bee visitors to almost every flower. Many bees are very active and hard to take and, once collected, they form one of the most difficult groups to identify to species. They have therefore suffered when named lists have been published.

Concerning the desirability of including them in descriptive lists of the constituents of various communities or regions, reference need only be made to the oligotropic relations existing between many bee species and flower species or groups, which link up irrevocably the female of the species with the community or communities in which its host plant or plants (from which alone pollen is collected), are found. Robertson (1926) presented a revised list of oligoleges from the Carlinville area. In Appendix A, a list is presented which is based on Robertson's bees and includes records of the presence of the various species in the Chicago region, along with any records of pollen collecting in the latter region. As explained in the appendix, all Chicago records are the writer's.

II. PARTIAL ECOLOGICAL CHECK-LIST OF THE BEES OF THE CHICAGO AREA

A. REQUIREMENTS THAT MUST BE MET BY A COMPLETE CHECK-LIST

Because of the close interdependence between bees and flowers (Robertson, 1895a), a complete ecological check-list of the bees of this area should give the following data:

1. Flowers on which the bee has been taken should be recorded, with the bee's sex, behavior, and abundance at different times of the day and during different periods of the blooming season for the flower species. Weather conditions should also be reported with each record.
2. The plant community in which the particular flower under consideration is growing should also be given and its general physical factors should be carried over into the summarized data for the bee species.
3. The seasonal flight for each species should be averaged over a period of several years, not merely extended by "records."
4. Consideration of abundance of visits to various flowers of various communities should permit the indication of a "preferred" community or

assembly, and perhaps a given set of physical conditions can then be indicated as "most suitable" for the species involved.

5. Nesting localities should be compared with data concerning flower visits to corroborate or offset such conclusions as may have been drawn from these data.

6. The information should be presented for all species of the area.

Accumulating such data for the bee fauna of the Chicago area would require that trips be made weekly or oftener to every major community and to many minor ones, and that every blooming plant known to have, or suspected of having, bee visitors should be watched for a period of at least half an hour, two or three different times during the day. This procedure would have to be repeated annually until the number of added species each year indicated mathematically the collection of approximately all species of the area. It would also involve careful observation of each bee before collecting it, with an almost constant recording of physical conditions of temperature, light, wind, and humidity. It would practically prevent the accumulation of any considerable number of specimens and would require almost constant work by one person during a considerable number of years.

B. WORK DONE TOWARD A CHECK-LIST

Because of the desirability of collecting as many different species of bees as possible in two years, and because of the necessity of collecting numbers of presumably the same species, the present work cannot present anything like a complete ecological check-list as described above. During the season of 1930, emphasis was placed on collecting numbers of individuals of the same species for experimental study. During a season of less intense collecting in 1931, emphasis was placed on collecting numbers of species for comparison with other regions, particularly the Carlinville area. As a result, the following list of bee species is far from complete. Little collecting was done in the dune regions, the main localities being Palos, Matteson, Lemont, and Ashburn, Illinois. Bees are, however, included from Somonauk, Waukegan, Zion, New Lenox, South Chicago, Willow Springs, Chicago, and Volo, Illinois, and Valparaiso, Tremont, and Dune Park, Indiana, as well as from other scattered localities. Collecting has been primarily in red-white oak (semi-climax), flood-plain, and prairie communities. There has been no hesitancy in collecting from ruderals and garden weeds nor from introduced or cultivated plants.

Where flower data are available or have been translated from the records, they have been included.

C. SCHEME OF CLASSIFICATION FOLLOWED

The general classification given below is a modification of Robertson (1904a). In the bumblebees, Frison (1919) has been followed. Two divergent stocks of bees are indicated.

I. Dasygastrae, Megachilidae, Stelididae.

II. Scopulipedes, Andrenidae, Nomadidae, Colletidae, Nomiidae, Protopididae, Halictidae, Dufoureaeidae, Macropididae, Panurgidae, Ceratinidae, Euceridae, Emphoridae, Anthophoridae, Melectidae, Epeolidae, Pasitidae, Bombidae, Apidae.

The general arrangement of the bees has been a subject of endless dispute and little is to be gained by entering into details. Changes in opinion by the same individual indicate the instability of the general classification and the two following quotations from Robertson indicate the fact that any worker in the field of bee taxonomy must be ready to readjust his opinions as he has done.

From Robertson (1899, page 340) :

To give *Psithyrus* this rank, I think, involves a great systematic error only equalled in the old physiological classification of Schuckard. The latter author calls those bees which carry pollen on their legs scopulipedes; those with abdominal brushes, dasygasters.

From Robertson (1924) :

As far as I can infer from the local species, I do not think they (Dasygastrae) have arisen from the other bees, but that they should be separated as one of two principal groups, Dasygastrae and Scopulipedes, with the latter divided into Apygidialia and Pygidialia.

This paper follows Robertson in considering these now as two separate groups.

D. PARTIAL CHECK-LIST OF BEES OF THE CHICAGO AREA, WITH CERTAIN ECOLOGICAL NOTES

The following list represents the results of 98 field trips distributed throughout two flower seasons, during which over 6,700 bees (exclusive of specimens of *Apis mellifera*), were brought in for experimental material or observed at work.²

The name in current usage, with author, is given first. Numbers of specimens collected in the Chicago region are then given, followed by ecological notes in certain cases, and then by a reference to the original description or to some vital citation of the species. Flower genera cited are representative only and no attempt is made to give more than one or two field sources for

² Since this work was completed, further collecting and identification of bees from the Chicago Region has added the following species:

Epeolus interruptus Robt.
Epeolus lectoides Robt.
Tricpeolus concavus (Cresson)
Melissodes vernoniae Robt.
Hoplitis cylindricus (Cresson)
Dianthidium notatum (Latreille)
Microstelis lateralis (Cresson)
Andrena erythrogastra (Ashmead)
Andrena geranii Robt.
Andrena mandibularis Robt.

Andrena milwaukeensis Graenicher
Andrena tridens Robt.
Andrena vicina Smith
Opandrena personata (Robt.)
Pterandrena asteris (Robt.)
Trachandrena rugosa (Robt.)
Trachandrena spireana (Robt.)
Pseudopanurgus asteris (Robt.)
Verbenapis verbenae Cockerell

the bee species. Among the Bremidae, Frison's names are given first, followed by Robertson's if they differ, the latter being in brackets.

ANTHOPHORIDAE

Amegilla walshii (Cresson) (1 ♀), August 5, Vernonia.

Anthophora Walshii Cresson (1869a) p. 290.

Anthemoea abrupta (Say) (30 ♀ 17 ♂), Pentstemon, ♀ June 26-July 8, ♂ June 20-July 2.

Anthophora abrupta Say (1837) p. 409.

Clisodon terminalis (Cresson) (55 ♀ 25 ♂), Pentstemon, ♀ June 20-September 7, ♂ June 24-August 4.

Anthophora terminalis Cresson, (1869a) p. 292.

APIDAE

Apis mellifera Linnaeus (many workers), all localities, all available flight weather.

Apis mellifera Linnaeus (1758).

BREMIDAE (flight appearance: ♀ wintered over, workers, males, females which will winter over).

Bremus affinus (Cresson) (1 ♀ 2 workers), ♂ June, workers August, Northeastern Illinois.

Bombus affinus Cresson (1864).

Bremus americanorum (Fabricius) [*Bombus americanorum* (Fabr.)] (68 ♀ 10 ♂ 112 workers), (1930 data—17 ♀ May, 39 June, 17 July; 1 ♂ July, 3 August, 5 September, 4 October; 31 workers July, 73 August, 7 September, 2 October).

Apis americanorum Fabricius (1775) p. 380.

Bremus auricomus (Robertson) [*Bombias auricomus* Robertson] (10 ♀ 27 workers), (1930 data—1 ♀ May, 6 June, 2 July, 2 August; 19 workers July, 11 August, 3 September).

Bombias auricomus Robertson (1903c) pp. 176, 177.

Bremus bimaculatus (Cresson) [*Bombus ridingsii* Cresson] (8 ♀ 1 ♂ worker), (1930 data—3 ♀ April, 5 May; 1 ♂ July; 1 worker July).

Bombus bimaculatus Cresson (1863) [*Bombus Ridingsii* Cresson (1878) p. 182].

Bremus borealis (Kirby) (2 workers), (1930 data—1 worker July, 1 August), Northeastern Illinois.

Bombus borealis Kirby (1837).

Bremus fervidus (Fabricius) 8 ♀ 11 ♂ 50 workers), (1930 data—1 ♀ April, 4 May, 3 June; 2 ♂ July, 8 August, 1 September; 11 workers July, 38 August, 1 September, 1 October).

Apis fervida Fabricius (1798) p. 274.

Bremus fervidus dorsalis (Cresson) (2 ♂ 1 worker), (2 ♂ August, 1 worker August).

Bombus fervidus var. dorsalis Cresson (1879a) p. 230.

Bremus impatiens (Cresson) [*Bombus impatiens* Harris] (10 ♀ 3 ♂ 35 workers), (1930 data—7 ♀ May, 3 June; 1 ♂ September, 2 October; 1 worker July, 30 August, 3 September).

Apis virginicus Olivier (1789) [*Bombus impatiens* Cresson (1864)].

Bremus rufocinctus (Cresson) (1 ♀ August; 2 workers August), Northeastern Illinois.

Bombus rufocinctus Cresson (1863).

Bremus rufocinctus albertensis (Cockerell) (2 workers August), Northeastern Illinois.

Bombus hyperboreus var. albertensis Cockerell (1909).

Bremus separatus (Cresson) [*Bombias separatus* (Cresson)] (14 ♀ 10 ♂ 49 workers), (1930 data—1 ♀ April, 2 May, 7 June, 2 July, 2 August; 7 ♂ August, 2 October; 17 workers July, 30 August, 2 September) Prairie.

Bombus separatus Cresson (1864).

Bremus vagans (F. Smith) [*Bombus consimilis* Cresson] (28 ♀ 7 ♂ 178 workers), (2 ♀ May, 20 June, 6 July, 1 August; 1 ♂ July, 5 August, 1 October; 57 workers July, 120 August, 2 October).

Bombus vagans Smith (1854) p. 399 [*Bombus consimilis* Cresson (1864)].

Psithyrus laboriosus (Fabricius) (5 ♀ 3 ♂), (♀ June, 4 July; 3 ♂ August).

Bombus laboriosus Fabricius (1804) p. 352.

Psithyrus variabilis (Cresson) (5 ♂), (2 August, 1 September, 2 October).

Apathus variabilis Cresson (1872) p. 284.

CERATINIDAE

Ceratina dupla Say (190 ♀ mixed with next two, 31 ♂), ♀ April 11-October 10; ♂ April 12-September 13, widespread, numerous.

Ceratina dupla Say (1837) p. 397.

Zaodontomerus calcaratus (Robertson) (3 ♀ and others mixed with *C. dupla*, 1 ♂), all August 5, Tithymalopsis, oak dunes.

Ceratina tejonensis Cresson (1864).

Zaodontomerus metallica (Smith) (♀ mixed with *C. dupla*, 4 ♂) ♀ April 11-October 10; ♂ June 14-September 7.

Ceratina metallica Smith, H. S. (1907).

EPEOLIDAE

Epeolus autumnalis Robertson (1 ♀ August 30).

Epeolus autumnalis Robertson (1902a) p. 81.

Epeolus pusillus Cresson (1 ♀ 4 ♂), ♀ August 22, *Rudbeckia hirta*.

Epeolus pusillus Cresson (1864).

Tripeolus cressonii (Robertson) (1 ♀ August 23) *Vernonia*.

Epeolus cressonii Robertson (1897) p. 344.

Tripeolus donatus (Smith, F.) (♀ 16 ♂ 13), ♀ August 9-26; ♂ August 12-26, *Cirsium*, prairie.

Epeolus donatus Smith (1854) p. 256.

Tripeolus helianthi (Robertson) (1 ♀ 1 ♂), ♀ August 5; ♂ July 4, *Helianthus divaricatus*.

Epeolus helianthi Robertson (1897) p. 344.

Tripeolus pectoralis (Robertson) (♀ 2), August 30, *Vernonia*.

Epeolus pectoralis Robertson (1897) p. 345.

Tripeolus simplex Robertson (3 ♀), August 1-22, *Helenium autumnale*, *Helianthus divaricatus*.

Tripeolus simplex Robertson (1903b) p. 285.

EUCERIDAE

Epimelissodes obliqua (Say) (7 ♀ 2 ♂), ♀ July 15-August 5; ♂ August 14-23; *Helenium*, *Helianthus*.

Macrocera obliqua Say (1837) p. 403.

Melissodes agilis Cresson (13 ♀ 142 ♂), ♀ July 11-September 2; ♂ July 11-September 2, *Helianthus* and many fall composites.

Melissodes agilis Cresson (1878) p. 204.

Melissodes bimaculata (LePelétier) (♀ 10 ♂ 12), ♀ June 5-September 13; ♂ July 2-August 26, *Monarda*.

Macrocera bimaculata LePelétier (1825) p. 527.

Melissodes boltoniae Robertson (possibly many of each sex, ♀ mixed with *M. vernoniana*, ♂ mixed with *M. simillima*, not clearly definable).

Melissodes boltoniae Robertson (1905a) p. 368.

Melissodes cnici Robertson (25 ♀ 51 ♂), ♀ August 9-September 5; ♂ July 11-August 26, *Cirsium*.

Melissodes cnici Robertson (1901) p. 230.

Melissodes coloradensis Cresson (6 ♀), August 30-September 5, *Helianthus*.

Melissodes coloradensis Cresson (1878) p. 200.

Melissodes nivea Robertson (8 ♂), August 5-23, *Helianthus*.

Melissodes nivea Robertson (1895b) p. 127.

Melissodes simillima Robertson (15 ♀, ♂ mixed with *M. boltoniae*, 75 or more if all *simillima*), ♀ August 23-October 4; ♂ June 27-August 30, *Verbena stricta*, *Vernonia*.

Melissodes simillima Robertson (1897) p. 355.

Melissodes trinodis Robertson (33 ♀ 92 ♂), ♀ July 2-September 7; ♂ July 11-September 5, *Rudbeckia* *Helianthus*, *Verbena*.

Melissodes trinodis Robertson (1901) p. 231.

Melissodes vernoniana Robertson (♀ mixed with *M. boltoniae*, 115 if all *vernoniana*; ♂ 18), ♀ June 27-September 12; ♂ June 27-July 19, *Vernonia*, *Verbena*.

Melissodes vernoniana Robertson (1905a) p. 368.

Tetralonia dilecta (Cresson) (12 ♀), June 20-July 6, *Rosa*, *Pentstemon*.

Melissodes dilecta Cresson (1878) p. 199.

Tetralonia rosae (Robertson) (9 ♀ 5 ♂), ♀ June 14-20; ♂ June 14.

Synhalonia rosae Robertson (1900) p. 54.

MEGACHILIDAE

Alcidamea simplex (Cresson) (60 ♀ 2 ♂), ♀ June 14-July 6; ♂ June 14, *Pentstemon*.

Heriades simplex Cresson (1864).

Alcidamea truncata Cresson (9 ♀ 2 ♂), ♀ June 21-28; ♂ June 14.

Alcidamea truncata Cresson (1878a) p. 108.

Ceratostoma lignaria (Say) (4 ♂), April 12-19, *Claytonia*.

Osmia lignaria Say (1837) p. 399.

Gnathosmia georgica (Cresson) (2 ♀ June 14 and 20) *Pentstemon*.

Osmia georgica Cresson (1878a) p. 105.

Monilosmia canadensis (Cresson) (10 ♀), June 20-28, *Pentstemon*.

Osmia canadensis Cresson (1864).

Osmia atriventris Cresson (7 ♀), June 14-July 2, *Pentstemon*.

Osmia atriventris Cresson (1864).

Osmia collinsiae Robertson (2 ♀ June 20 and 28), *Pentstemon*.

Osmia major Robertson (1902a) p. 79.

Osmia distincta Cresson (85 ♀), June 14-July 26, *Pentstemon*.

Osmia distincta Cresson (1864).

Osmia pumilia Cresson (42 ♀ 13 ♂), ♀ May 10-June 28; ♂ April 11-May 10, *Pentstemon*.

Osmia pumila Cresson (1864).

Neotrypetes barbatus (Robertson) (20 ♀ 3 ♂), ♀ July 8-29; ♂ June 4-5, *Monarda*.

Trypetes barbatus Robertson (1903c) p. 171.

Neotrypetes productus (Robertson) (10 ♀ 2 ♂), ♀ June 28-July 28; ♂ June 14, *Erigeron*.

Trypetes productus Robertson (1905) p. 236.

Anthemois centuncularis (Linnaeus) (3 ♀ 6 ♂), ♀ July 10-August 23; ♂ July 10-August 23.

Apis centuncularis Linnaeus (1766-8).

Cyphophyga montivaga (Cresson) (9 ♀ 6 ♂), ♀ June 14-August 26; ♂ June 24-August 23, *Pentstemon*.

- Megachile montivaga* Cresson (1878a) p. 124.
- Megachile brevis* Say (11 ♀ 15 ♂), ♀ July 6-September 11; ♂ June 20-September 11, widespread, numerous.
- Megachile brevis* Say (1837) p. 407.
- Megachile generosa* Cresson (1 ♀ 1 ♂), ♀ June 24; ♂ July 19, Verbena, *Monarda punctata*.
- Megachile generosa* Cresson (1878a) p. 125.
- Megachile mendica* Cresson (9 ♀ 15 ♂), ♀ June 27-September 5; ♂ July 2-August 27, Helenium, Rudbeckia.
- Megachile mendica* Cresson (1878a) p. 126.
- Megachile petulans* Cresson (39 ♀ 1 ♂), ♀ July 4-August 19; ♂ July 30, Vernonia, Pentstemon.
- Megachile petulans* Cresson (1878a) p. 127.
- Oligotropus campanulae* Robertson, (2 ♀ 7 ♂), ♀ July 25-26; ♂ June 25-July 25, *Campanula americana*.
- Oligotropus campanulae* Robertson (1903c).
- Sayapis pugnata* (Say) (16 ♀ 4 ♂), ♀ July 2-August 2; ♂ July 2-July 15, Silphium, Vernonia.
- Megachile pugnata* Say (1837) p. 408.
- Sayapis sayi* (Cresson) (29 ♀ 9 ♂), ♀ July 11-September 11; ♂ July 30-August 30, Lepachys.
- Megachile Sayi* Cresson (1878a) p. 119.
- Xanthosarus latimanus* (Say) (65 ♀ 16 ♂), ♀ June 24-September 20; ♂ June 27-August 23, Vernonia, Rudbeckia, and other Composites.
- Megachile latimanus* Say (1859) p. 169.
- Coelioxys alternata* Say (4 ♀ 1 ♂), ♀ July 11-September 11; ♂ July 30, Verbena.
- Coelioxys alternata* Say (1837) p. 401.
- Coelioxys germana* Cresson (2 ♀), August 5 and 6, Helianthus.
- Coelioxys germana* Cresson (1878a) p. 102.
- Coelioxys modesta* Smith (2 ♀ 1 ♂), ♀ August 30; ♂ July 4, Verbena, Pentstemon.
- Coelioxys modesta* Smith (1854) p. 271.
- Coelioxys octodentata* Say (2 ♂), July 6-August 19, Melilotus.
- Coelioxys octodentata* Say (1859).
- Coelioxys rufitarsis* Smith (2 ♀), July 25-August 23, Solidago, Helianthus.
- Coelioxys rufitarsis* Smith, F. (1854) p. 271.
- Coelioxys sayi* Robertson (5 ♀ 9 ♂), ♀ June 28-August 30; ♂ July 31-August 9, Helianthus, Verbena.
- Coelioxys sayi* Robertson (1897) p. 346.
- NOMADIDAE**
- Centrias americanus* (Kirby) (11 ♀ 8 ♂), ♀ June 14-21; ♂ May 10-June 14, Erigeron.
- Nomada americana* Kirby (1837) p. 269, pl. 6, fig. 3.
- Holonomada placida* (Cresson) (2 ♀ 5 ♂), ♀ September 7-13; ♂ September 7, Solidago.
- Nomada placida* Cresson (1864).
- Holonomada superba* (Cresson) (1 ♀ 2 ♂), ♀ June 14; ♂ August 5-16.
- Nomada superba* Cresson (1864).
- Holonomada vincta* (Say) (1 ♀ 7 ♂), ♀ July 30; ♂ July 19-30, Helianthus.
- Nomada vincta* Say (1837) p. 401.
- Nomada cressonii* Robertson (1 ♀ May 10).
- Nomada cressonii* Robertson (1893) p. 275.
- Nomada sayi* Robertson (2 ♀ 2 ♂), ♀ June 27; ♂ 21-27.
- Nomada sayi* Robertson (1900a) p. 293.

Xanthidium luteoloides (Robertson) (1 ♂ May 12), Salix.

Nomada luteoloides Robertson (1895b) p. 124.

PASITIDAE

Holcopasites illinoensis (Robertson) (1 ♀ July 29).

Phileremus illinoensis Robertson (1891b) p. 64.

STELIDIDAE

Chelynia foederalis (Smith) (1 ♂ June 14).

Stelis foederalis Smith (1854) p. 275.

ANDRENIDAE

Andrena arabis Robertson (1 ♀ April 19), Claytonia.

Andrena arabis Robertson (1897) p. 334.

Andrena carlini Cockerell (25 ♀ 19 ♂), ♀ April 14-May 14; ♂ April 4-26, Claytonia, Crataegus.

Andrena carlini Robertson (1902b) pp. 190 and 192.

Andrena corni Robertson (1 ♀ June 20), Cornus.

Andrena corni Robertson (1900) p. 50.

Andrena erythronii Robertson (11 ♀), April 19, Claytonia, Salix.

Andrena erythronii Robertson (1891b) p. 53.

Andrena hirticincta Provancher (19 ♀ 14 ♂), ♀ September 7-20; ♂ August 19-September 13, Solidago.

Andrena hirticincta Viereck (1916) pp. 710, 711, 715, 718.

Andrena nasonii Robertson (2 ♀ 1 ♂), ♀ April 19-May 3; ♂ April 13, Crataegus.

Andrena nasonii Robertson (1895b) p. 120.

Andrena nubecula Smith (7 ♀), September 2-20, Solidago.

Andrena nubecula Smith (1853) p. 117.

Andrena platyparia Robertson (19 ♀ 17 ♂), ♀ June 14-21; ♂ June 14-21, Cornus, Prunus.

Andrena platyparia Robertson (1895b) p. 119.

Andrena salictaria Robertson (2 ♀ 33 ♂), ♀ April 12; ♂ April 12-19, Salix.

Andrena salictaria Robertson (1905) p. 236.

Opandrena miserabilis (Cresson) (1 ♀ May 14), Claytonia.

Andrena flavo-clypeata Robertson (1891b) p. 55, also earlier references.

Opandrena cressonii (Robertson) (3 ♀ 10 ♂), ♀ May 14-June 21; ♂ May 14-19, Salix, Claytonia, Prunus.

Andrena cressonii Robertson (1891b) p. 56.

Opandrena ziziae (Robertson) (5 ♀), June 14.

Andrena ziziae Robertson (1891b) pp. 55, 56.

Opandrena serotina (Cresson) (20 ♀ 4 ♂), ♀ June 27-July 5; ♂ June 27-28, Rhus.

Andrena serotina Robertson (1893) p. 148.

Parandrena andrenoides (Cresson) (12 ♀ 4 ♂), ♀ April 12-May 4; ♂ May 4, Salix.

Panurgus andrenoides Cresson (1878a) p. 62.

Pterandrena aliciae (Robertson) (37 ♀ 22 ♂), ♀ July 30-August 19; ♂ July 30-August 16, Helianthus, Rudbeckia.

Andrena aliciae Robertson (1891b) p. 57.

Pterandrena helianthi (Robertson) (39 ♀ 32 ♂), ♀ August 5-September 20; ♂ July 27-September 12, Helianthus.

Andrena helianthi Robertson (1891b) p. 55.

Pterandrena krigiana (Robertson) (2 ♀), June 20, Krigia.

Andrena krigiana Robertson (1901) p. 229.

Pterandrena pulchella (Robertson) (2 ♀), August 30-September 5, Helianthus.

Andrena pulchella Robertson (1891b) p. 57.

- Pterandrena rudbeckiae* (Robertson) (6 ♀), June 27-July 11, Rudbeckia.
Andrena rudbeckiae Robertson (1891b) p. 56.
Pterandrena solidaginis (Robertson) (59 ♀ 19 ♂), ♀ September 7-13; ♂ September 2-13, Solidago.
Andrena solidaginis Robertson (1891b) p. 55.
Ptilandrena erigeniae (Robertson) (83 ♀ 44 ♂), ♀ April 6-May 3; ♂ April 6-May 3, Claytonia, Hepatica.
Andrena erigeniae Robertson (1891b) p. 52.
Ptilandrena g. maculati (Robertson) (4 ♀), May 14, *Geranium maculatum*.
Andrena g. maculati Robertson (1897) p. 333.
Ptilandrena polemonii (Robertson) (4 ♀ 3 ♂), ♀ May 3-10; ♂ May 3, Polemonium.
Andrena polemonii Robertson (1891b) p. 54.
Trachandrena claytoniae (Robertson) (1 ♀ 5 ♂), ♀ May 14; ♂ May 14, Claytonia.
Andrena claytoniae Robertson (1891b) p. 59.
Trachandrena forbesii (Robertson) (3 ♂), April 12, Salix.
Andrena forbesii Robertson (1891b) p. 59.
Trachandrena heraclei (Robertson) (1 ♀ April 4), Salix.
Andrena heraclei Robertson (1897) p. 336.
Trachandrena hippotes (Robertson) (3 ♀), May 14, Prunus.
Andrena hippotes Robertson (1895b) p. 120.
Trachandrena mariae (Robertson) (2 ♀ 9 ♂), ♀ April 12; ♂ April 12, Salix.
Andrena mariae Robertson (1891b) p. 58.
Trachandrena quintilis (Robertson) (1 ♀), June 6.
Andrena quintilis Robertson (1898) p. 46.
- COLLETIDAE**
- Colletes americanus* Cresson (2 ♀ 3 ♂), ♀ September 20-October 4; ♂ August 30-September 7, Aster, Solidago.
Colletes americana Cresson (1868).
Colletes armatus Patton (13 ♀), August 23-September 13, Aster, Solidago.
Colletes armata Patton (1879a) p. 365.
Colletes compactus Cresson (12 ♀ 18 ♂), ♀ September 12-October 4; ♂ August 30-September 12, Aster, Solidago.
Colletes compacta Cresson (1868) p. 166.
Colletes eulophi Robertson (63 ♀ 25 ♂), ♀ July 18-August 5; ♂ June 6-September 2, Allium.
Colletes eulophi Robertson (1891b) p. 61.
Colletes inaequalis Say (1 ♀), May 17.
Colletes inaequalis Say (1837) p. 391.
Colletes latitarsis Robertson (1 ♀), July 25.
Colletes latitarsis Robertson (1891b) p. 60.
Colletes nudus Robertson (1 ♀), July 11, Ceanothus.
Colletes nudus Robertson (1898) p. 43.
Colletes validus Cresson (24 ♀ 47 ♂), ♀ May 3-4; ♂ May 3-4, Salix and nests in sand of lake shore near Zion City.
Colletes valida Cresson (1868) p. 165.
Colletes willistonii Robertson (1 ♂ June 27).
Colletes willistonii Robertson (1891b) p. 60.
- DUFOUREIDAE**
- Halictoides marginatus* (Cresson) (6 ♀ 35 ♂), ♀ August 30-September 5; ♂ August 30-September 12, Helianthus.
Panurgus marginatus Cresson (1878a) p. 62.

HALICTIDAE (Females winter over, produce other females, then males, in most cases).

Agapostemon radiatus (Say) (9 ♀ 14 ♂), ♀ May 10-September 13; ♂ July 31-August 30, widespread and numerous.

Halictus radiatus Say (1837) p. 394.

Agapostemon splendens (LePéletier) (5 ♂), August 19, oak dunes.

Halictus splendens LePéletier (1836-46) p. 283.

Agapostemon texanus Cresson (4 ♀ 4 ♂), ♀ May 10-October 4; ♂ August 4-September 20, widespread, Cirsium and Composites for males.

Agapostemon texanus Cresson (1872) p. 255.

Agapostemon viridulus (Fabricius) [*virescens* (F.)] (117 ♀ 17 ♂), ♀ June 14-October 4; ♂ August 4-October 5, very widespread and numerous Pentstemon.

Apis viridula Fabricius (1775) p. 342.

Augochlora fervida Smith (1 ♀ August 5), oak dune.

Augochlora fervida Smith (1853) p. 81.

Augochlora viridula F. Smith (27 ♀), May 10-August 19, widespread and numerous.

Augochlora viridula Smith (1853) p. 81.

Chloralictus albipennis (Robertson) (36 ♀ several ♂), ♀ June 15-July 18, Melilotus.

Halictus albipennis Robertson (1890) p. 317.

Chloralictus coeruleus (Robertson) (16 ♀ several ♂), ♀ June 28-August 12, Monarda.

Halictus coeruleus Robertson (1893) p. 146.

Chloralictus cressonii (Robertson) (53 ♀ numerous ♂), ♀ May 10-August 14, general and numerous.

Halictus cressonii Robertson (1890) p. 317.

Chloralictus graenicheri Ellis (5 ♀), July 19, sandy soil.

Halictus graenicheri Sandhouse (1924) p. 4.

Chloralictus pilosus (Smith) (31 ♀ numerous ♂), ♀ May 3-July 19, very widespread and general.

Halictus pilosus Smith (1853) p. 71.

Chloralictus sparsus Robertson (27 ♀ several ♂), ♀ May 10-August 26, very widespread and numerous.

Chloralictus sparsus Robertson (1902) p. 249.

Chloralictus tegularis (Robertson) (15 ♀ several ♂), ♀ June 5-August 21, widespread and numerous.

Halictus tegularis Robertson (1890) p. 318.

Chloralictus versatus Robertson (97 ♀ numerous ♂), ♀ June 2-August 21, most widespread and very numerous.

Chloralictus versatus Robertson (1902) p. 249.

Chloralictus vierecki Crawford (17 ♀), July 19, sandy soil, Ceanothus.

Halictus vierecki Sandhouse (1924) p. 4.

Chloralictus zephyrus (Smith) (50 ♀ numerous ♂), ♀ July 4-18, widespread and numerous.

Halictus zephyrus Smith, F. (1853) p. 68.

Curtisapis coriacea (Smith) (99 ♀ 16 ♂), ♀ May 10-September 20; ♂ August 4-October 12, widespread and general.

Halictus coriaceus Smith, F. (1853) p. 70.

Curtisapis forbesii (Robertson) (22 ♀ 2 ♂), ♀ April 12-August 4; ♂ July 15-August 26, Salix, general.

Halictus forbesii Robertson (1890) p. 315.

Curtisapis fuscipennis (Smith) (2 ♀), June 21-August 2, Rhus.

Halictus fuscipennis Smith, F. (1853) p. 67.

- Dialictus anomalus* Robertson (36 ♀ some ♂), ♀ June 14-July 29, Pentstemon, Rudbeckia; visit records differ much from Robertson.
- Halictus anomalus* Robertson (1892).
- Evyllaenus arcuatus* (Robertson) (81 ♀ 14 ♂), ♀ May 14-July 29; ♂ August 2-September 12, Rhus, widespread.
- Halictus arcuatus* Robertson (1893) p. 145.
- Evyllaenus foxii* (Robertson) (1 ♀), August 4, Aster.
- Halictus gracilis* Robertson (1890) p. 316.
- Evyllaenus nelumbonis* (Robertson) (4 ♀), June 28, *Nymphaea lutea*.
- Halictus nelumbonis* Robertson (1890) p. 316.
- Evyllaenus pectinatus* (Robertson) (1 ♀), July 11.
- Halictus pectinatus* Robertson (1890) p. 315.
- Evyllaenus pectoralis* (Smith, F.) (36 ♀ 1 ♂), ♀ May 10-August 7; ♂ July 30, widespread and numerous.
- Halictus pectoralis* Smith (1853) p. 68.
- Evyllaenus quadrimaculatus* (Robertson) (88 ♀ 18 ♂), ♀ June 14-August 15; ♂ August 4-9, Sonchus, Rudbeckia.
- Halictus quadrimaculatus* Robertson (1890) p. 316.
- Evyllaenus truncatus* (Robertson) (13 ♀) July 4-15, Ceanothus.
- Halictus similis* Robertson (1900) p. 52.
- Halictus lerouxii* LePéletier (21 ♀ 21 ♂), ♀ May 10-August 4; ♂ July 29-September 13, widespread and numerous.
- Halictus lerouxii* LePéletier (1836-46) p. 372.
- Halictus parallelus* Say (2 ♀), July 4, Rhus.
- Halictus parallelus* Say (1837) p. 397.
- Halictus texanus* (Cresson) (19 ♀), July 4-5, Sandy soil, to light at night, our only dusk flyer.
- Sphecodes texana* Cresson (1872) p. 249.
- Odontalictus ligatus* (Say) (243 ♀ 102 ♂), ♀ May 10-September 12; ♂ July 26-October 4, extremely widespread and numerous, favors Compositae.
- Halictus ligatus* Say (1837) p. 396.
- Oxystoglossa confusa* (Robertson) (64 ♀ 40 ♂), ♀ May 10-October 10; ♂ August 2-September 12, very widespread and numerous.
- Augochlora confusa* Robertson (1897) p. 324.
- Oxystoglossa pura* (Say) (2 ♀ 2 ♂), ♀ May 10-October 4; ♂ August 4-16.
- Halictus purus* Say (1837) p. 395.
- Oxystoglossa similis* (Robertson) (49 ♀ 4 ♂, or mixed with *O. confusa*), ♀ May 10-July 26; ♂ July 19-August 30, widespread.
- Augochlora similis* Robertson (1893) p. 146.
- Paralictus cephalicus* (Robertson) (2 ♀), July 26, one more pale than other, both much more than Robertson's. *Cirsium*, Cornus.
- Halictus cephalicus* Robertson (1892).
- Seladonia fasciata* (Nylander) (47 ♀ 7 ♂), ♀ May 10-October 4; ♂ July 26-September 5, widespread and numerous.
- Halictus fasciatus* Robertson (1895b) p. 117.
- Machaeris stygia* (Robertson) (1 ♀ 1 ♂), ♀ August 16; ♂ September 2.
- Sphecodes stygius* Robertson (1893) p. 145.
- Proteraner ranunculi* (Robertson) (1 ♀ 1 ♂), ♀ June 15; ♂ June 15, Apocynum.
- Sphecodes ranunculi* Robertson (1897) p. 318.
- Sphecodes arvensis* Patton (1 ♀), July 26, Pycnanthemum.
- Sphecodes arvensis* Patton (1880) p. 230.

Sphecodes clematidis Robertson (1 ♀), April 12.

Sphecodes clematidis Robertson (1897) p. 320.

Sphecodes heraclei Robertson (3 ♀), August 5-28, Solidago.

Sphecodes heraclei Robertson (1897) p. 318.

Sphecodes minor Robertson (1 ♀), July 4.

Sphecodes minor Robertson (1898) p. 45.

Sphecodium cressonii Robertson (1 ♀), June 28, above Halictid nests.

Sphecodium cressonii Robertson (1903) p. 104.

Sphecodium pimpinellae (Robertson) (1 ♀), May 10, Taenidia.

Sphecodes pimpinellae Robertson (1900) p. 51.

MACROPIDIDAE

Macropis ciliata Patton (3 ♀ 2 ♂), ♀ July 5-26; ♂ July 5, Steironema.

Macropis ciliata Patton (1880a) p. 31.

Macropis morsei Robertson (12 ♀, 1 ♂), ♀ July 5-26; ♂ July 5, Steironema.

Macropis morsei Robertson (1897) p. 336.

PANURGIDAE

Calliopsis andreniformis Smith (45 ♀ 20 ♂), ♀ June 16-August 19; ♂ June 28-August 19, prairie.

Calliopsis andreniformis Smith, F. (1853).

Heterosarus parvus (Robertson), (1 ♂), July 4, Ceanothus.

Calliopsis parvus Robertson (1892).

Pseudopanurgus albitarsis (Cresson) (7 ♀ 13 ♂), ♀ August 19; ♂ July 15-September 5, Helianthus.

Panurgus albitarsis Cresson (1872) p. 260.

Pseudopanurgus compositarum (Robertson) (1 ♀), October 10, Aster.

Calliopsis compositarum Robertson (1893) p. 274.

Pseudopanurgus labrosus (Robertson) (4 ♂), August 19-September 5, Rudbeckia.

Panurginus labrosus Robertson (1898) p. 48.

PROSOPIDIDAE

Prosopis illinoensis Robertson (51 ♀ 5 ♂), ♀ June 15-September 13; ♂ June 15-August 12, Solidago.

Prosopis illinoensis Robertson (1896a) p. 138.

Prosopis pygmaea Cresson (47 ♀ 12 ♂), ♀ June 14-September 7; ♂ June 14-August 4, widespread, Apocynum.

Prosopis pygmaea Cresson (1869) p. 272.

Prosopis saniculae Robertson (2 ♀), August 9-23, Daucus.

Prosopis saniculae Robertson (1896a) p. 137.

Prosopis sayi Robertson (17 ♀ 3 ♂), ♀ June 15-August 26; ♂ June 14-August 4, Apocynum.

Prosopis Sayi Robertson (1904) p. 273.

Prosopis ziziae Robertson (57 ♀ 15 ♂), ♀ June 15-August 19; ♂ June 13-August 12, Apocynum, Zizia, widespread.

Prosopis ziziae Robertson (1904) p. 273.

Data given in the above list, and more specific, fragmentary records not included, seemed to be insufficient for generalizations concerning suspected bee-adaptations. For this reason it was determined to compare the Carlinville and Chicago areas and, if sufficient similarity of fauna and flora was indicated, certain of Robertson's data could be tested to see if they would supply predictions of bee-adaptations for experimental confirmation or dis-

proof or for later confirmation or negation by additional collecting data from the Chicago region.

III. COMPARISON OF THE CARLINVILLE AND CHICAGO AREAS

A. FLORAS OF THE TWO REGIONS

Carlinville, Illinois, is located almost on a line between Chicago and St. Louis, and is approximately 250 miles southwest of Chicago, south of Springfield, almost in the Austro-riparian Area of the Austral Zone of Merriam (1898). Often shown in the prairie country, it is much more characteristically surrounded by mesophytic forest, running to what may be called the flood-plain type in the Chicago area. Sections of country having prairie characteristics are readily available but there is nothing in the region to compare with the dune series of the Chicago area.

Chicago, and its immediate vicinity, becomes the focus of several divergent lines of plant groups. Northern species work down the lake from Wisconsin, eastern species move in through Indiana with a very unique flora characteristic of the dunes, southern species move up and are available in the dunes, while the more characteristically western species of Iowa and beyond are also to be expected. Both Chicago and Carlinville, however, are included in Merriam's Carolinian Area of the Upper Austral Zone.

Fuller (1925) describes the more clearly defined plant communities (called by him "associations") of the Chicago region. These are given in Appendix B. In his paper, Fuller lists the more common plants of these communities and omits all weeds and ruderals.

Robertson, in numerous papers (1887, 1889, 1890a, 1891a, 1892a, b, 1893a, 1894a, 1895, 1896b, c, 1898a and 1899a) reported studies in the Carlinville area and in a work entitled "Flowers and Insects" (1928) presented a bibliography and gave a complete list of the flowers he had studied, together with the observed visitors and other data.

A comparison of the numbers of plant species found in the Carlinville region and in the Chicago region shows the expected similarities. Table I shows the highest percentage of plants in both regions to be found in high prairie, but the data on plants not listed in Fuller (1925) give a mesophytic character to the Carlinville area.

In addition to the plants considered in Table I, the majority of plants studied by Robertson (1928) and not given by Fuller (1925) yet stated by Fuller verbally or by Pepoon (1927) to be found in the Chicago area are plants primarily found in flood-plain, climax, red and white oak, or prairie communities. Numbers of these studied by Robertson are as follows: in flood-plain, 45 or 28.5%; in climax, 12 or 7.6%; in red and white oak, 20 or 12.6%; in low prairie, 27 or 17.0%; in high prairie, 10 or 6.3%; and in all

other communities, 44 or 27.8%. These figures do not include weeds, ruderals, introduced plants, and others not belonging to one or more of the endemic communities.

The figures in Table I and the additional ones of the preceding paragraph, tend to justify the assumption that there are decided similarities in the Chicago and Carlinville areas, and that bees found common to both areas might be expected to present, in the Chicago region, flower-reactions essentially similar to those exhibited and reported in the region of Carlinville.

TABLE I—Comparison of numbers of flowers in the communities of Fuller with the numbers of these flowers studied by Robertson

Community of Fuller	Flowers given in Fuller (1925)	Number of these flowers studied by Robertson (1928)	Percentage studied by Robertson
I-1.....	8	0	0.0
I-2.....	19	4	21.0
I-3.....	24	10	41.7
I-4.....	46	18	39.1
I-5.....	91	42	46.1
I-6.....	84	37	44.0
I-7.....	75	37	49.3
I-8.....	26	9	34.6
II-1.....	28	19	67.9
II-2.....	80	64	80.0
III.....	96	28	29.2
IV.....	69	7	10.1
V.....	13	5	38.5
VI.....	53	28	52.8
VII.....	129	77	59.8
VIII.....	47	17	36.2
Total.....	888	402	45.2

However, as stated, distinct differences in the flora are also to be noted, particularly a preponderance of more mesic plants in the Carlinville area, and these differences will also tend to make the results obtained from observations in the Chicago region differ from conclusions drawn in the Carlinville area. These differences become more apparent when the bees are considered.

B. BEE FAUNAS OF THE TWO REGIONS

The data to be presented on this point are based on the work of Robertson published both as separate papers and finally in his "Flowers and Insects" (1928). It was found necessary to rework these data from the form given by Robertson, in which the flowers were listed by families and genera, with bee visitors added. For use in the present work, the bees were arranged by

families and genera and the flowers Robertson found them on were tabulated after each bee species. Degree of abundance of visits to each flower was also carried over from Robertson's book.

When completed, this list was compared with the list given in the partial check-list (Section II) and it was observed that some bees reported from Chicago were absent from Carlinville, and a large number reported from Carlinville had not yet been taken in Chicago. Yet of the bees reported from Chicago for 1930 and 1931, 157 of the 169 or 92.9% are given by Robertson, though species now unidentified will doubtless cut down this percentage when identified. Of those given by Robertson, 157 of the 297 or 52.8% are reported from Chicago, and this percentage will doubtless be increased with further identification and collection.³ These figures would seem to further justify extensive use of Robertson's data in studies made in this region.

C. THE FLOWER-BEE RELATIONS OF THE TWO REGIONS

Although it has not been possible to obtain more than an indication of the flower-bee relations for the Chicago region, data have been obtained which would seem to show that, in certain cases at least, Robertson's Carlinville results can be approximately confirmed for the Chicago region.

The 27 species of flowers given in Table II have been observed closely and detailed lists of the bees visiting them in the Carlinville and Chicago regions have been made up. It is not practicable to publish either of these lists. In study of the summary of this comparison in Table II it must be remembered that "as yet unidentified" species will alter final results and it is to be inferred that further collecting from year to year in Carlinville would also, perhaps, shift Robertson's results, to a certain degree.

In Table II, following the assigned number and the name of the flower species of each of the 27 examples chosen, the next column gives the number of species of bees, common to both regions, found on the plant or flower species. For example, 18 of the bee species recorded by Robertson as visiting *Rhus glabra*, have also been taken on this species by the writer in the Chicago region. The next column gives 0 for *Rhus glabra* and indicates that no additional species not taken by Robertson on this flower have been taken in the Chicago area. Then the 18 of the next column indicates that Robertson recorded 18 additional species on this flower, which have not yet been taken by the writer on the same flower. The final column compares the percentage of species common to both regions with the total number of bee species recorded from both regions as visiting the flowers of *Rhus glabra*.

Attention is called to the fact that these data are not submitted as evidence for adaptation of bees to certain plant species. These data are believed to

³ In an earlier footnote, in connection with the check-list, 19 species were listed as identified or collected in 1932. Of these 19, 16 appear in Robertson 1928, thus raising the number of Carlinville bees found in the Chicago Region to 173 out of 297 or 58.2%.

furnish evidence that, of a given number of bee species taken during many years of collecting on a flower in the Carlinville region, a large percentage of the same restricted list of bees, and relatively few others, will be taken on the same flower in the Chicago region. Naturally the more "general" bees (visiting a considerable variety of flowers) will appear several times in any list and will be collected where a rare bee will be missed. However, a long list of bee species will appear in even as short a list of flowers as that of Table II.

TABLE II—*Comparisons of the species of bees that visited twenty-seven selected flower examples found in both the Carlinville and Chicago regions*

Plant Species	Species of bees common to both regions	Species taken only in Chicago	Species taken only in Carlinville	Percentage of species taken in both regions
<i>Rhus glabra</i>	18	0	18	50.0
<i>Apocynum androsaemifolium</i>	4	4	2	40.0
<i>Asclepias syriaca</i>	7	0	19	26.9
<i>Impatiens biflora</i>	6	1	2	66.6
<i>Campanula americana</i>	10	1	6	58.8
<i>Sambucus canadensis</i>	6	1	2	66.6
<i>Cirsium lanceolatum</i>	16	2	15	48.4
<i>Rudbeckia hirta</i>	18	4	9	58.0
<i>Silphium integrifolium</i>	13	0	8	61.9
<i>Vernonia fasciculata</i>	16	5	10	51.6
<i>Geranium maculatum</i>	13	0	22	37.1
<i>Monarda fistulosa</i>	14	2	14	46.6
<i>Baptisia leucantha</i>	1	1	0	50.0
<i>Melilotus alba</i> (intr.).....	24	0	20	54.5
<i>Sanguinaria canadensis</i>	4	0	3	57.1
<i>Phlox glaberrima</i>	0	0	0	100.0
<i>Claytonia virginica</i>	33	0	25	56.9
<i>Steironema ciliatum</i>	1	3	1	20.0
<i>Hepatica acutiloba</i>	5	1	6	41.8
<i>Ceanothus americanus</i>	16	3	8	59.2
<i>Prunus serotina</i>	10	1	20	32.2
<i>Rosa humilis</i>	8	0	6	57.1
<i>Rubus villosus</i>	14	0	36	28.0
<i>Cephalanthus occidentalis</i>	7	0	24	22.5
<i>Philadelphus grandiflorus</i>	4	1	6	36.3
<i>Gerardia grandiflora</i>	5	1	4	50.0
<i>Pentstemon laevigatus</i>	19	6	3	67.8
Total.....	292	37	289	47.2
Species involved.....	85	29	121	

The bee-species flower records common to both regions on the 27 flowers total 292. These are made up from records of 85 different species of bees. The bee species records from these 27 flowers, given by Robertson in addition to the 292 common to both regions, total 289. These records are made up by 121 species of bees, 55 of which have not yet been taken at all by the writer, while 66 of them have been taken by him but not in the relations to flower species indicated by Robertson in this column. Then, finally, 37 species records are given for the 27 flowers, obtained in the Chicago region and based on 29 species of bees all collected by Robertson but not in the flower

relations given by this column. It will also be observed that if 292 flower bee-species records are common to both regions for these 27 flowers, and if 618 total flower bee-species records are included, 47.2% of the records will be shown as being similar in both the regions under discussion.

Data of the collection made in the Chicago region confirm in general the relations laid down by Robertson (1928). *Evylaeus nelumbonis* was taken only on the flowers of *Nymphaea advena* and, as Robertson indicates, no other visitor was observed. Species of *Salix* presented the wide variety of spring Andrenidae suggested by Robertson. *Helianthus* and its allies showed the great numbers of visits of *Melissodes obliqua*, *M. coloradensis*, and *M. agilis*, of *Pterandrena helianthi*, and of the unique *Halictoides marginatus*; *Solidaginis* presented its oligolege *Pterandrena solidaginis*, and its large numbers of *Colletes armatus* and *C. compactus*; *Cirsium* yielded many specimens of *Melissodes cnici*, *Triepeolus donatus*, and *Bremidae*; and *Rudbeckia* led in *Tetralonia dilecta*, *Melissodes trinodis*, and *Pterandrena aliciae*.

Certain variations would be expected in the Chicago region, from relations prevailing in the Carlinville region. One striking confirmation yet variation is indicated by relations of *Steironema* and *Macropis*. Robertson (1926) includes *Macropis steironematis* as an oligolege of *Steironema*. None of this species were taken in the Chicago area, but two species of *Macropis* not reported from Carlinville were taken on plants of this genus. These bees were *Macropis ciliata* and *M. morsei*.

The Chicago region yields the conspicuous *Andrena hirticincta* which does not occur near Carlinville. Here is found the northern *Chloralictus graenicheri* and the eastern *C. vierecki*, neither of which go much further south. The striking *Halictus texanus* occurs in Wisconsin, the Dakotas, Texas, and in the Southern Chicago region, but is not found near Carlinville. The northern *Bremidae* come into the northern limits of the Chicago area and are of course absent from Carlinville. Not only does the interesting *Zaodontomerus calcaratus* occur in this region, but the eastern *Zaodontomerus metallicus* has been taken in the dunes region and thus is presented the phenomenon of three species, these two and *Ceratina dupla*, all found in one region and all with the females indistinguishable. The more northern *Colletes valida* was very numerous along the western shores of Lake Michigan.

The data given in this section indicate that it is justifiable to expect a majority of the bees occurring in both areas to bear in this region the same relations to plants that they bear to the same species of plants in the Carlinville area.

IV. COMPARISON OF AVAILABLE DATA CONCERNING THE APPARENT ADAPTATIONS OF CERTAIN BEE SPECIES TO PLANT COMMUNITIES, WITH DATA CONCERNING BEE SURVIVAL

In this section it is proposed to examine available observational data in an attempt to ascertain whether biotic factors or physical factors are of primary importance in determining what habitats shall be frequented by a given species of bee. If it is decided that a sufficient number of species are apparently governed to a large extent by physical factors in their distribution among and visits to various habitats, then experimental studies on certain of these species or larger groups, under controlled conditions of temperature and humidity, should offer some corroboration of apparent adaptation to these particular habitats, for the habitats themselves are to a large extent products of temperature and humidity.

All of Robertson's (1928) observations on the visits of bees to flowers, which relate to plants that are known to occur in the Chicago area, were transferred over into a detailed list to give a prediction of the number of flower-species that each of his bees would be expected to visit in the Chicago area, with information concerning the number of species of flowers visited either frequently or abundantly in each plant community. To supplement these records, others were available from the 1930 and 1931 collections made in this area.⁴

These data are drawn upon later in this work, to furnish comparison records for certain species, genera, and families of bees, in order to determine if any correlation exists between the character of the physical conditions of the communities most characteristically visited by the bees, and the type of physical conditions maintained experimentally in the laboratory, under which the given group of bees survives for the maximum period of time.

RELATIONS OF BEES TO PARTICULAR PLANT COMMUNITIES

1. Species that seem Definitely to be Expected in Certain Communities Only, according to Robertson's Data, with Confirmation from Local Data Where Possible.

Among the *Anthophoridac*, *Emphoropsis floridana* is interesting as being placed in only I-7 and VII (see Appendix B for plant community symbols). However, only males are recorded and they have not been taken by the writer. *Clisodon* may be called "mesic." Others of the family are quite generally distributed.

Apis mellifera has become a very cosmopolitan bee following its intro-

⁴ The writer wishes here to acknowledge the assistance of Dr. Charles H. Seevers, Mr. E. Morton Miller, and Dr. B. H. Willier, in the collection of specimens, and the assistance of Mrs. Hazel M. Pearson in the checking of records and manuscript, and the collecting of specimens and preparing of labels and records.

duction by man, that great disturber of ecological factors. This introduced species appears to exert an influence upon native bees, which is visible to any student of the native species. So efficient is it as a collector of pollen and honey and so ubiquitous has it become, there can be no question but what its inroads cause a serious diminution in the food supply of native bees, particularly in bad seasons.

In the *Bombidae* (*Bremidae*) listed by Robertson (1928), *Bombias scutellaris* is distinctly a prairie bee, most abundant in community II-2. *Bombus americanorum* is the most cosmopolitan of the *Bombidae* and of the bees as a whole, exceeding even *Apis mellifera*. Not only has it been recorded to make 346 flower-community visits, but very many of these are frequent or abundant. *Bombus consimilis* would seem to react most favorably to I-6, 7, and VII, adapted more to moist woods than to drier conditions. On the other hand, the inquilines *Psithyrus laboriosus* and *P. variabilis* seem to fall into open country of prairie, with a rather striking absence or near absence from the series of dune or morainic uplands.

Ceratina dupla is another very widely distributed bee present in abundance upon numerous flowers in many communities.

Emphor bombiformis is absent, apparently, from the dune-morainic series and has not yet been taken by the writer. The same holds true for *Melitoma taurea*.

Epeolus bifasciatus, *Triepeolus concavus*, *T. concolor*, *T. lunatus*, and *T. remigatus* are the most striking examples of the general trend of adaptation of this family to prairie, particularly high prairie.

Among the *Euceridae* it is of interest to note that *Melissodes* is predominantly a prairie bee, while *Tetralonia* runs to moister woods of the dune or morainic series and to other associations such as flood-plain, with comparative absence from prairie.

Considering the *Megachilidae*, we observe that *Centrosmia*, *Ceratosmia*, *Diceratosmia*, and *Osmia pumila* run to I-6, 7, and VII; that *Gnathosmia* might seem to run to II-2; and that others of *Osmia* are more general. *Hoplitis cylindricus* would seem to favor I-4, II-2, and VI, regions with less humidity; while *Neotrypetes productus* runs mainly to II-2. *Megachile addenda* is found mainly in I-5 and I-6; *M. brevis* is very cosmopolitan with 147 flower-community visits but is dominantly in prairie. *M. petulans* is general but very well represented in III-5; *M. strophostylis* is to be expected only in the dry I-2 and I-3; and *Sayapis pugnata* and *S. sayi* are dominantly II-2. The common *Xanthosarus* is also very dominantly prairie though rather well distributed through the communities. Most visits and abundant visits of *Coelioxys* are recorded from II-2.

In the family *Nomadidae* there is a rather general distribution of certain species, with others showing definite restrictions. Numerous visits to communities III and IV, particularly III-3, are to be noted.

Holcopasites illinoensis runs to I-4 and II-2 both of which are regions of higher evaporation rate.

Microstelis lateralis and *Stelidium tryptetinum* of the Stelididae both run most commonly to II-2.

Most bees of the genus *Andrena* are to be expected in I-5, 6, 7, and VII. There are some with records in I-3 and 4, as well as a considerable number in III and VI. This genus is practically absent from II. *Opandrena cressonii*, *O. miserabilis*, and *O. personata* are numerous and cosmopolitan. The first of these is very characteristically a flood-plain bee, though it shows frequent records in I-3 and I-4. All three show a greater proportionate abundance in VI than is observed among the bees considered above. *O. personata* is most characteristically found in I-6 of the dune or morainic series. Among the *Pterandrena*, only *P. krigiana* with its records in I-5 and 6 and *P. lauracea* with no records save I-5 and 6 deviate from the general rule of predominance in prairie. *P. rudbeckiae* shows an abundant record also in both I-8 and VIII. The three *Ptilandrena* species show no visits whatsoever save to I-6, 7, and VII, where all are found. In *Trachandrena*, III-3 figures abundantly. Several of these bees run to a rather general distribution, with emphasis on I-5, 6, 7, and VII. However, *T. forbesii*, *T. hippotes*, and *T. mariae* favor I-3, 4, and 5 in the dune or morainic series, while *T. heraclei*, *T. obscura*, and *T. quintilis* are practically absent from the series. The two latter show only records in II-2 of prairie. *Trachandrena spiraeana* shows an abundant record only in V.

In the *Colletidae*, there is also a variety of distribution. *Colletes albescens* is recorded from I-4 and II-2; *C. aestivalis*, *C. americanus*, *C. productus*, *C. robertsonii*, *C. similis*, and *C. speciosus* favor II-2 of prairie; *C. brevicornis* falls only into VI; *C. latitarsis* runs to I-3, and I-5; while the others are more general in distribution.

Among the *Halictidae* *Agapostemon radiatus* and *A. splendens* may be considered as running more toward I-6, 7, and VII, though they hold up well in I-4 and prairie. *A. texanus* and *A. viridulus* run to prairie and more to I-4. Climax, I-7, is not much frequented by either. *Augochlora fervida* is very well represented in I-4, II-1, 2, and III-5. But *A. viridula* is dominantly in I-6, 7, and VII, though it also makes many visits to prairie. *Chloralictus albipennis* and *C. pruinosus* are most abundant in II-2, with good representation in I-2, 3, and 4. *C. coeruleus* favors VII, while *C. cressonii*, *C. sparsus*, and *C. zephyrus* are relatively more abundant in the more moist dune groups and in flood-plain. Other species of the genus are rather evenly distributed. *C. versatus* with 306 records is the most cosmopolitan of the species. *Curtisapis forbesii* seems to be best adapted, of the three in this genus, to dry conditions; while *C. coriacea* should be sought in red and white oak, in climax, and in flood-plain. Considering the genus *Evylaeus*, *E. arcu-*

atus centers in I-5 of the dune series, while *E. foxii* centers in I-4 according to frequency of visit, though more flowers of 1-7 are visited. *E. nelumbonis* is most characteristic of III-2, as the name might imply. *E. pectoralis* centers in II-2 and VII, while *E. quadrimaculatus* is most characteristic of VII. *Halictus lerouxii* is generally distributed, but *H. parallelus* centers in II-2 and I-4. *Odontalictus ligatus* is well distributed but predominantly visits both II-2 and II-1. It is really a prairie bee but a remarkable number of its visits are to Compositae. *Oxytroglossa confusa* is general and numerous; *O. pura* favors I-6, 7, and VII; and *O. similis* emphasizes I-4, II-2, and VI, though I-5, 6, and VII are often visited. *Seladonia fasciata* is rather evenly and generally distributed.

Considering the inquilines related to the genus *Sphecodes*, we find rather general distribution where sufficient data are available, though *Machaeris stygia*, *Sphecodes arvensis*, and *Sphecodium cressonii* are more probably to be found in II-2 than elsewhere.

Among the *Macropididae*, *Macropis steironematis* is the only one studied by Robertson. His data (1928) place this bee mainly in II-1. It is also to be sought in VIII and II-2.

Paranomia nortonii is to be expected in II-2. One other unidentified species of *Nomiidae* has been taken in II-2.

The *Panurgidae* are most characteristically found in prairie, though some are well distributed. *Pseudopanurgus labrosiformis* runs rather more toward VII than any of the other communities.

Prosopididae are generally distributed save *P. thaspæi* and *P. saniculae* of VII only; *P. nelumbonis* of III-2; and *P. ziziae*, which is most characteristically to be found in II-2.

2. Percentage of Bees that can be Considered Restricted to Certain Communities.

Making use of the unpublished predictions concerning bee visits to plant communities (arrived at by applying Robertson's 1928 summary to Fuller's plant communities, Appendix B) it becomes evident that certain species may be said to offer indications of specializations that would fit them to specific environments; other are not so specialized. In comparing these two bee groups, only bees that have been taken on five or more species of flowers are included, unless they are oligoleges of one or more species of flowers. Out of 240 species given by Robertson (1928) with suitable information available, 168 or 70.0% may be said to show a broad distribution through plant communities of quite different physical characters. Seventy-two or 30.0% may be considered as visiting frequently or abundantly only one type of community or at least communities having somewhat similar conditions of humidity and evaporation.

3. Conclusions to be Drawn from Oligoleges.

The list of oligoleges given by Robertson (1926) is presented in Appendix A. Bee names followed by a "c" have been taken by the writer in the Chicago region. Bees followed also by a second "c" indicate species which have been observed collecting pollen from plants indicated by Robertson, and from no others. It will be observed that Robertson gives 83 species of oligoleges which are considered valid species in his 1928 book. Thirty-seven or 44.5% have been taken in the Chicago area, and 19 or 22.9% have been checked while collecting in this area and have not been disproved as oligoleges.

Comparison of the oligolege-species with the species apparently characteristic of one type of community shows that 29 or 36.6% of Robertson's 79 available oligoleges would be considered as fitting into one particular community with more emphasis than into others of different physical characteristics.

The question of oligoleges brings up Robertson's views concerning the interactions between flowers and bees. The present work has been questioning the possible existence of limited and selected bee constituents for many or certain of the plant communities of the Chicago area. Throughout all of the numerous papers published by Robertson, there is no mention of plant communities. Robertson has, however, presented detailed studies of the structures and colors of flowers visited by various species of bees (1923 and 1925). It is thus evident that he considers the relations between flower and bee as paramount, with the bee, if necessary, following flowers of a given species or genus into regions of varying humidity and evaporation rate.

The following eight oligoleges, chosen from Robertson's list (1926) indicate the variable nature of the plant-community bee-visit predictions which can be made from Robertson's data (1928). Plant community symbols are explained in Appendix B. The name of the bee is followed by the name of the plant group to which the host belongs. This name in turn is followed by the number of plant species of the group which are visited for pollen by the oligolege (according to Robertson). The communities in which these host plants grow are then given.

Andrena arabis—Cruciferae—10 species. Taken by Robertson on three species, communities V, VII, 41, and 45. Species on which it was not taken occur in I-5, 6, 7, III-3, 21, 23, 32, 33, 34, and 41.

Andrena erythrogastra—Salix—5 species. Taken by Robertson on all five species, a true oligolege.

Andrena salictaria—Salix—5 species. Taken by Robertson on four species, communities I-3, 4, III-3, and VII. Salix occurs also in I-5 but this bee was not taken on the species that may occur in this community.

Iomelissa violae—Viola—6 species. Taken by Robertson on three species, communities I-5, 6, 7, II-2, and VII. Only one other community is represented by the three species not visited, namely, II-1.

Colletes latitarsis—Physalis—3 species. Taken by Robertson on all three species, communities I-3, 5, II-1, and 41.

Megachile generosa—Leguminosae—39 species. Taken by Robertson on five species, collecting pollen on three. Communities represented are I-2 and I-3, 27, 33, 34, 43, and 47. These and all other flower records seem to indicate a reaction that may be called positive to a sandy or dry environment. Other species in the family cover almost all communities and categories.

*Melissodes cnic*i—Cirsium—4 species. Taken by Robertson on three of the four, the fourth blooming before the bee flies; communities II-1, II-2, and 29.

Emphor bombiformis—Hibiscus—3 species. Taken by Robertson on two of them, in communities VII and 47. The one not visited would come under the category 35.

4. Bee Species and Plant Communities.

Judging from the collection from the Chicago area, and from the predictions to be made from Robertson's collection (1928), it would seem to be clearly evident that a majority of the bee species will visit flowers in a number of different plant communities. In some cases, these visits will clearly

TABLE III—Total species of bees from Robertson's data predicted by families as visitors to the various plant communities of Fuller

Bee Families	Genera	Species	COMMUNITIES																										
			I						II		III					IV				V	VI	VII	VIII	IX	X				
			2	3	4	5	6	7	8	1	2	1	2	3	4	5	1	2	3	4									
Long-tongued bees:																													
1. Anthophoridae.....	5	5	1	2	4	3	4	3	0	3	2	1	0	0	0	1	1	0	1	1	0	2	4	2					
2. Apidae.....	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
3. Bombidae.....	3	10	6	5	6	8	8	7	4	8	9	3	4	7	0	8	6	3	5	6	4	9	8	7					
4. Ceratinidae.....	2	2	0	2	2	2	2	2	1	1	2	1	1	2	0	1	1	0	2	1	2	2	2	2	2	2	2	2	
5. Emphoridae.....	2	2	0	0	0	0	0	0	0	2	1	0	0	1	0	2	0	0	0	0	0	1	2	0					
6. Epeolidae.....	3	18	2	2	6	12	8	1	7	13	16	2	0	3	0	13	11	0	0	0	0	11	11	12					
7. Euceridae.....	9	32	13	11	15	22	15	8	8	21	27	5	0	9	0	16	11	2	1	1	1	19	24	17					
8. Megachilidae.....	21	42	9	11	27	29	31	18	12	28	33	10	0	7	0	14	8	0	9	9	4	32	28	19					
9. Melectidae.....	2	2	0	0	2	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0					
10. Nomadidae.....	8	23	0	10	13	14	16	13	1	6	17	1	0	13	0	3	3	0	4	5	3	14	20	7					
11. Pasitidae.....	1	2	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0					
12. Stelididae.....	5	6	0	0	2	2	1	1	0	1	2	0	0	0	0	0	0	0	0	0	0	3	1	2					
13. Xylocopidae.....	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1					
Total.....	63	146	32	44	80	94	84	54	54	84	115	24	6	43	0	60	43	6	23	24	15	96	103	70					
Short-tongued bees:																													
51. Andrenidae.....	7	52	0	19	22	33	36	32	3	17	27	0	0	25	0	13	13	0	9	19	11	33	43	25					
52. Colletidae.....	1	15	4	8	5	9	7	4	2	7	14	0	0	5	0	5	3	0	2	2	0	8	8	7					
53. Dufoureae.....	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	1	1					
54. Halictidae.....	17	56	9	28	39	43	41	34	19	27	45	10	12	38	0	29	20	5	17	23	12	42	48	33					
55. Macropididae.....	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1					
56. Nomidae.....	1	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1					
57. Panurgidae.....	8	16	0	0	3	9	4	2	5	11	12	1	0	0	9	8	0	0	0	0	0	4	11	7					
58. Prosopididae.....	1	9	0	3	3	4	7	4	0	5	6	0	2	4	0	5	2	0	1	1	5	6	8	5					
Total.....	37	151	14	58	73	101	95	76	29	69	107	11	14	72	0	62	47	5	29	45	28	93	120	80					
Total All Bees.....	100	297	46	102	153	195	179	130	63	153	222	35	20	115	0	122	90	11	52	69	43	189	223	150					

be made in search of food from any or from certain definite kinds of flowers. However, in other cases, these different plant communities will be seen to have certain definite physical characteristics that are much in common.

In the case where a species of bee visits several different plant communities, it is often still possible to add this bee species with confidence to the lists of animals found in these communities, provided that care is taken to record the time of year as well. It will then be possible to return to that community the next year and to expect, at the proper time, to collect that particular species of bee.

It seems reasonable to predict that as many or more bees will be found distinctive for each community as there are at present other insects, keeping in mind of course the total number of existing species, both of insects in general and of bees in particular. It is scarcely probable that the predictions based on Robertson's records alone, will be found seriously at variance with actual facts when more extensive collecting is done in this region.

TABLE IV—Abundant and frequent records of bee visitors, predicted from Robertson's data by families for the various plant communities of Fuller

Bee families	COMMUNITIES																							
	I							II		III					IV				V	VI	VII	VIII		
	2	3	4	5	6	7	8	1	2	1	2	3	4	5	1	2	3	4						
Long-tongued bees:																								
1. Anthophoridae....	0	0	2	2	2	1	0	2	1	1	0	0	0	0	0	0	0	0	0	2	2	1		
2. Apidae.....	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1		
3. Bombidae.....	1	1	5	4	6	6	1	6	6	1	0	4	0	5	3	1	1	1	1	4	6	3		
4. Ceratinidae.....	0	1	1	1	2	0	1	1	2	1	0	2	0	1	1	2	1	1	0	2	2	1		
5. Emphoridae.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0			
6. Epeolidae.....	0	0	2	4	1	0	0	3	12	0	0	1	0	4	2	0	0	0	0	6	7	5		
7. Euceridae.....	3	2	7	9	5	4	1	17	18	2	0	2	0	6	4	1	0	0	10	17	9			
8. Megachilidae.....	4	4	8	9	15	6	2	11	18	2	0	3	0	3	1	0	1	1	0	18	14	5		
9. Melectidae.....	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0			
10. Nomadidae.....	0	6	8	7	10	0	0	1	8	0	0	9	0	1	1	0	2	2	0	5	12	1		
11. Pasitidae.....	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0			
12. Stelididae.....	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1			
13. Xylocopidae.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Total.....	9	15	36	38	43	18	6	37	69	8	1	22	0	21	13	3	6	6	2	48	63	27		
Short-tongued bees:																								
51. Andrenidae.....	0	12	14	21	20	16	1	2	15	0	0	15	0	3	4	0	0	8	2	21	31	14		
52. Colletidae.....	0	3	1	7	3	2	1	3	6	0	0	3	0	3	1	0	0	1	0	8	3	3		
53. Dufoureae.....	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1			
54. Halictidae.....	0	7	17	17	16	13	2	12	25	2	8	16	0	9	2	0	2	6	2	20	28	12		
55. Macropididae.....	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1			
56. Nomidae.....	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0			
57. Panurgidae.....	0	0	2	4	3	0	2	7	9	1	0	0	0	3	2	0	0	0	0	2	7	5		
58. Prosopididae.....	0	1	1	1	2	0	0	2	4	0	0	1	0	0	0	0	0	0	3	4	5	0		
Total.....	0	23	35	52	44	31	6	27	62	3	8	35	0	18	9	0	2	15	7	53	74	36		
Total All Bees....	9	38	71	90	86	49	12	64	131	11	9	57	0	39	22	3	8	21	9	103	137	63		

At this point it might be well to call attention to the fact that bees of the families *Apidae*, *Bremidae* (*Bombidae*), and *Halictidae* seem to be mostly general in distribution throughout the year as well as throughout various habitats, extremes of environment of course excepted. The other bees generally appear to be more restricted both in time and variety of communities visited.

TABLE V—Total bee-species-flower-species visits predicted from Robertson's data by families for the various plant communities of Fuller

Bee families	COMMUNITIES																							
	I							II		III					IV				V	VI	VII	VIII		
	2	3	4	5	6	7	8	1	2	1	2	3	4	5	1	2	3	4						
Long-tongued bees:																								
1. Anthophoridae.....	1	2	5	11	22	7	0	5	6	1	0	0	0	1	1	0	1	1	0	4	20	4		
2. Apidae.....	4	5	10	21	25	29	5	19	39	1	1	7	0	15	4	1	1	4	3	19	61	11		
3. Bombidae.....	10	10	27	73	130	75	12	88	174	3	4	17	0	55	22	3	5	9	7	63	214	29		
4. Ceratinidae.....	0	2	8	21	38	30	5	14	40	1	1	8	0	9	5	0	3	2	0	29	60	9		
5. Emphoridae.....	0	0	0	0	0	0	0	5	3	0	0	1	0	3	0	0	0	0	0	1	4	0		
6. Epeolidae.....	2	2	7	19	7	1	7	39	75	2	0	3	0	25	12	0	0	0	0	19	33	16		
7. Euceridae.....	15	13	25	46	51	25	16	81	149	5	0	11	0	49	18	2	1	1	1	37	111	25		
8. Megachilidae.....	15	16	43	73	109	53	20	88	204	10	0	14	0	41	16	0	9	9	5	72	147	38		
9. Melectidae.....	0	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0			
10. Nomadidae.....	0	13	22	31	55	20	1	9	54	1	0	29	0	3	3	0	4	5	4	39	107	12		
11. Psitidae.....	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0			
12. Stelididae.....	0	0	2	3	3	1	0	1	10	0	0	0	0	0	0	0	0	0	0	4	2			
13. Xylocopidae.....	0	0	1	0	0	0	0	0	3	0	0	0	0	1	1	0	0	0	0	1	1			
Total.....	47	63	153	299	440	241	66	349	763	24	6	90	0	202	82	6	24	31	26	289	761	147		
Short-tongued bees:																								
51. Andrenidae.....	0	31	46	91	109	99	3	23	58	0	0	59	0	16	14	0	9	24	12	110	278	37		
52. Colletidae.....	4	12	7	24	11	11	2	4	36	0	0	10	0	18	4	0	2	3	0	22	35	12		
53. Dufoureiidae.....	0	0	0	1	0	0	0	1	2	0	0	0	0	1	1	0	0	0	0	0	1			
54. Halictidae.....	9	50	127	223	266	224	43	176	427	11	18	116	0	114	40	6	20	35	23	254	527	108		
55. Macropididae.....	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	2			
56. Nomiidae.....	1	0	2	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0			
57. Panurgidae.....	0	0	4	12	9	2	5	27	34	1	0	0	0	16	10	0	0	0	0	8	27	10		
58. Prosopididae.....	0	3	5	16	19	14	0	15	38	0	3	8	0	16	2	0	1	1	6	22	68	9		
Total.....	14	96	191	369	414	350	53	265	601	12	21	193	0	181	71	6	32	63	41	416	937	190		
Total All Bees.....	61	159	344	668	854	591	119	615	1364	36	27	283	0	383	153	12	56	94	67	705	1698	337		

B. ABUNDANCE OF BEES IN VARIOUS PLANT COMMUNITIES

As stated previously, the number and abundance of flower and community visits have been predicted for all of Robertson's flowers and their bee visitors, where both are known to occur in the Chicago region. If these records are summarized they afford information for comparison with data already presented by other workers, such as Park (1930) with Coleoptera. Although the community-bee relationships are not records but are calculated or predicted, and although they are drawn from the Carlinville area, which has no

dunes, there is sufficient similarity of plant species and bee species (Sections III A and B) to permit prediction in part for the dunes series of the Chicago region and to set forth certain conditions and relations which may be confirmed or disproved by future collecting.

In presenting this information concerning bee families and plant communities, four tables are given. The first one, Table III, gives the total numbers of species of bees in each family predicted for each plant community. Thus, Family 1, Anthophoridae, 5 genera, 5 species,—1 species visits community I-2, 2 visit I-3, 4 visit I-4, etc. Table IV predicts, from records of frequent or abundant visits only, the total number of species of bees of each family which will be found frequently or abundantly in the various communities. Table V gives total bee-species flower-species visits for each family of bees, predicted for each plant community. For example, if in a given family six species of bees are found in a given community, and six flowers are recorded for this community, in this table the records might show that each of the six bees visited each of the six flowers and thus the flower-species bee-species visits would be 36. A given species of bee thus may appear a

TABLE VI—Summary of data of Tables III, IV, and V*

Community	No. of bee species predicted	No. of bee species abundant or frequent	No. of flower species visited	Ratio of flowers to bees	No. of flower bee-species visits
I-1.....	0	0	0	.....	0
I-2.....	46	9	4	1-11.5	61
I-3.....	102	38	10	1-10.2	159
I-4.....	153	71	18	1- 8.5	344
I-5.....	195	90	47	1- 4.15	668
I-6.....	179	86	56	1- 3.19	854
I-7.....	130	49	47	1- 2.76	591
I-8.....	63	12	12	1- 5.25	119
II-1.....	153	64	44	1- 3.47	615
II-2.....	222	131	73	1- 3.04	1364
III-1.....	35	11	2	1-17.5	36
III-2.....	20	9	3	1- 6.66	27
III-3.....	115	57	13	1- 8.84	283
III-4.....	0	0	0	.....	0
III-5.....	122	39	25	1- 4.88	383
IV-1.....	90	22	10	1- 9.0	153
IV-2.....	11	3	3	1- 3.66	12
IV-3.....	52	8	3	1-17.3	56
IV-4.....	69	21	4	1-17.25	94
V.....	43	9	5	1- 8.6	67
VI.....	189	103	34	1- 5.56	705
VII.....	223	137	120	1- 1.85	1698
VIII.....	150	63	18	1- 8.31	337
Total.....	2362	1032	551	1- 4.28	8616

*These record the numbers of bee species predicted for each plant community, based on Robertson's 1928 data, the numbers of bee species predicted from the same source as visiting each plant-community abundantly or frequently, and the numbers of bee-species flower-species visits for each community, predicted also from Robertson's data. In addition to these comparisons, the ratios between bee species predicted and flower species from Robertson's 1928 work, known to be present, are also calculated, together with the numbers of these flower species in each community.

number of times in each community. This was of course not true in either Table III or Table IV. In Table VI, the total visits from all three preceding tables are given for comparison with the numbers of flower species in each community. A ratio between total species of bees and total species of flowers is also given for comparison.

Considering mainly the dune and morainic series, the prairie series, and the flood-plain plant community, more species of flowers are recorded from the red and white oak than from any other of the dune or "I" series. But these visits are exceeded in number by the numbers in the high prairie community and more than doubled by those in the flood-plain community. If the number of different species of bees found in the communities be considered, the peak falls at black oak or I-5. If only the frequent or abundant visits are considered, the peak falls in black oak or I-5, due to the visits of the short-tongued bees, principally *Colletes* and the *Panurgidae*. The peak of the long-tongued bees is in I-6. In the high prairie, there are 222 species of bees, 131 visiting abundantly or frequently the 73 species of flowers. Astonishingly enough, 223 species of bees, 137 abundantly or frequently, visit the 120 species of flowers of flood-plain. In other words, the same number of bees visit nearly twice the number of flower species. Table VI gives a ratio for each community between flower species found in, and bee species visiting, each community. The ratio for high prairie is seen to be 1 to 3.04. That of flood-plain is seen to be 1 to 1.85. In brief comment on this table, it might be said that the more species of plants in a given community, the fewer species of bees will visit each plant, which is what one would expect.

For the dune series, considering the families that have most species, while studying the abundant-frequent records only (Table IV), it may be noted that the peak for *Bombidae* falls in red and white oak, and climax; the peak of *Epeolidae* in I-5, or black oak; that of *Euceridae* in black oak; that of *Megachilidae* strikingly in red and white oak; that of *Nomadidae* in red and white and with none at all in climax; the *Andrenidae* almost divided between black oak and red and white oak; *Colletidae* in black oak; and the *Halictidae* equally divided between pineland and black oak, with red and white oak a close third. The peak of *Panurgidae* falls in black oak, and that of *Protopididae* in red and white oak. It is to be noted that there is then a complete absence of abundant or frequent records of the inquilines *Epeolidae* and *Nomadidae*, and of the short-tongued *Panurgidae*, from climax.

Halictidae and *Andrenidae* show the following comparative relationships: if the number of species of bees taken abundantly or frequently in high prairie and flood-plain be compared, there are 15 *Andrenidae* and 25 *Halictidae* in high prairie, and 31 *Andrenidae* and 28 *Halictidae* in flood-plain. But if the number of bee-flower-species records of these two families be compared for high prairie and flood-plain, we observe that there are 58 for *Andrenidae*

in high prairie, and 427 for *Halictidae*, but that for flood-plain there are 278 of *Andrenidae* and 527 of *Halictidae*. The differences observed may be explained by the fact that the prairie *Andrenidae* are practically all oligoleges of restricted plant groups.

C. TOLERATION EXPERIMENTS TO TEST PHYSIOLOGICAL ADAPTATION OF BEES TO PHYSICAL CONDITIONS OF PLANT COMMUNITIES

1. Materials, Technique, and Apparatus Used.

a. Previous work with native bees.—Wild bees have scarcely been considered a favorite material for laboratory experimentation in the past, though certain efforts have been made to handle them under conditions paralleling their native surroundings, with the object of furthering knowledge concerning nesting habits, parasites, and sex ratios. Fabre's work (1879-1907), particularly with *Osmia*; Frison's work (1926a) with *Bremus*; and Rau's work (1924) with *Bremus* and (1928) with *Ceratina* will serve as examples of the type to which reference is made. But still less has been done along the lines of experiment with individual bees. An example of this type is the unpublished work of Buchsbaum and Boyer at the University of Chicago, discussed by Allee in "Animal Aggregations" (1931). These workers studied *Melissodes agilis* males in an attempt to determine the relative importance of light and temperature as ecological factors inducing an inactivity which might be variously spoken of as sleep, hibernation, or mere inactivity. They took advantage of the sleeping habits of these bees, collecting them while they were still inactive in early morning on *Helianthus*, where they were found sometimes in numbers of fifteen to twenty, or even more, upon one flower.

b. Collecting technique.—The actual problem of collecting varies with the bee species or genus, or even family. Each comes to present a separate question of procedure and for efficient work it is necessary to remember or relearn whether the bee will permit approach with vial and cork and will fly up or will drop off the flower, and whether the net must be placed over the flower and time given for the bee to rise from the ground into it, or whether the net must be swung down or up or sideways. Certain species are particularly gifted with the tendency to escape through the net; in this respect, the males are the worst offenders of the sexes. The males of *Chloralictus* are extremely agile; small *Prosopidids* and *Andrenids* are hard to keep; females of *Ceratina dupla* give very much trouble; and males of *Ceratina dupla* are almost impossible to retain in the average net. No straight sweeping has been done. It has been the exceptional bee specimen, in the collection under discussion, that has not been located on the flower and the method of its capture worked out in advance.

Crushing the bee lightly by twisting the net serves as an excellent means of keeping it in place after it has climbed as high up the net as is desired in

its positive response to sunlight. It is then possible to insert the vial or bottle with little danger of the bee's escaping and with little danger of being stung. The collection at hand and the experiments here described have been made with exactly seven stings, each one due to carelessness and over-confidence. The general statement may be made that no bee's sting is prolongedly painful, the female bumblebees being worse than the giant *Xylocopidae* of the tropics.

All bees in the field seem to be photopositive. It has been possible, by judicious maneuvering of the vial, to keep six quite large bees inside while it is uncorked. Any that escape are due to random movements on the part of the bees. It must be added that some of the *Prosopididae*, in particular, are slow to react and they and other bees are inclined to be exploratory in reaction, thus adding additional delay in completing the response to sunlight by climbing up in the vial.

The net must be held over the early *Andrenidae* visiting *Claytonia virginica*. Cutting off the light sends them off the flower to the ground, from which they arise after a minute or so, sometimes having crawled along over the ground and out under the net before coming up. This is particularly true of both sexes of *Ptilandrena erigeniae*. Perhaps a vial over the flower is the safest means if this bee is approached from behind.

Anthophorids can usually be taken right on the flower by covering them with the bottle.

Apis mellifera is best taken with the net; a half dozen in the net can easily be transferred to a vial at one time.

Bombidae are taken easily with a large bottle, or in the net with any kind of sweep.

Ceratinids are almost impossible to take without a side swing of the net and must be transferred to the jar or vial at once. They are easily taken while inside of flowers such as *Pentstemon laevigatus*.

Eucerids are easily taken while on the flowers but the net is safest.

Halictids are individual problems. Often they can be taken with the vial or bottle but some species cannot be so collected.

Some Colletids are taken with the vial or bottle. I have taken some with a vial over the nest entrance.

Prosopidids are best taken with the net if the mesh is small.

All of the *Megachilidae* are easy to take, except *Sayapis* which must often be taken on the wing.

Nomadids, Epeolids, and other inquilines such as *Sphecodes* and *Coelioxys* seem particularly quick in reacting to approach. Many must be taken on the wing.

In general, the males are far more alert than the females and must be taken on the wing much more often.

Bees taken in copula, otherwise alert, are often insensible to being struck by the net and continue in copula on the net.

Melissodes agilis almost convinces one that its females may in some cases seek the males instead of the reverse condition, which usually prevails among bees. At times extreme difficulty has been experienced in collecting one or two females, while males were relatively common and were often found resting on the flowers. At least two females have been seen approaching the males, and one of the resulting pairs was taken in copula.

c. Non-experimental survival in captivity.—Before it was possible to set up the apparatus and begin experiments, a considerable number of bees were successfully brought in to the laboratory and fed honey mixed with glucose, or even glucose alone dissolved in water. Except for the females and large males and workers of the *Bombidae*, all bees were brought home in 6 and 8 dram vials, with a small twig inserted between vial and cork. It was found practically impossible to predict the viability of the temporary inhabitants of any given vial. Any number up to five large, or even twenty small, bees might survive 100% with or without one or more flowers in the vial, or there might be 100% mortality. Neither the species of bee nor the elapsed time between collecting and return to the laboratory had any correlation, in so far as could be determined. This observation may well be borne in mind during consideration of the experimental data. It indicates a variability in the vitality of any group of bees of the same species taken during a day's collecting, which may be indicative in turn of a correlation between "elapsed time since emergence" and "remaining vigor." It seems hard to account otherwise for the fact that bees taken in the morning at nine o'clock may out-live others, apparently larger, of the same species, taken at four o'clock, when both are used in experiments beginning at five-thirty and running for two hours or more.

In some instances, the larger *Bombidae* were brought back in cylindrical cages made of wire screening. These seemed to survive no longer than those brought back in the vials.

It may be well to note that some of the smaller Halictids survived for over six weeks, living two or three females to the vial, and with each being fed a small drop of the honey each day. *Seladonia fasciata* and some of the *Chloralictus* females, particularly *cressonii*, would most amusingly simulate death when their vials were disturbed to insert the card bearing the honey. (This habit is employed in nature where these bees often fall to the ground the instant their flower is disturbed.) In some instances they would show no movement after this reaction, until from fifteen to thirty seconds, or even longer, had elapsed.

Reconsideration of methods employed in collecting these bees to be used for experiment would suggest that such experiments can only be followed

the specimen jar F containing also the hair hygrometer and thermometer. Jars A, AA, and F are supported by the rack S in the bottom of the bath. To the right, on an elevated stand, are four sulphuric-acid jars C, two of them serving as safety jars, a fume-removing jar D, and a calcium chloride jar E. Beneath this stand is the Pitot tube H in its brass tube G and with its U-tube-gauge J. The glass vials, open but screened at both ends, which contain the experimental material are shown in their wire rack behind the hair hygrometer in F.

Compressed air in desired quantities is admitted to the first jar marked A, containing tap water, by the tube marked AIR INLET. It passes to the bottom of the jar by the glass tube through the water-tight cork and enters the jar at 1. It is washed and passes out at 2, entering the next jar at 1, is washed a second time and passes out at 2 to enter the third jar for the third washing, only to leave by 2 and enter the safety bottle AA by inlet 1. This bottle serves to collect any surplus water and prevents flooding of the sulphuric-acid bottles in case of a break in the air line.

From jar AA the washed air may leave by two exits controlled by valves V1 and V2. If high humidity is desired, V1 is closed and the saturated air passes at once into jar B by 1 and leaves it by 2 to enter jar F by entrance 1. Circulating upward, this air passes freely through the screened vials and then leaves by 2 to enter the brass tube G where the Pitot tube records its rate of flow as it escapes by the AIR OUTLET.

If dry air is desired, the valve V2 is closed and V1 is opened, all washed air from AA passing at once into the concentrated sulphuric acid of the first C jar by the entrance 1. It leaves by 2 and enters the second jar where there is a second bathing in concentrated sulphuric-acid. The two additional jars marked C are both safety jars, from the last of which the air passes into the flask D by the glass tube leading to the bottom of the flask at 1. This flask contains glass-wool, bone-black, and charcoal, and removes sulphuric-acid fumes. Leaving by the exit 2, the dry air enters the bottom of the jar E containing calcium chloride and passes up through it for a final drying. Returning by tube M, the air enters the mixing jar B by entrance 3, leaves it by exit 2, and then enters the bee-jar F.

If humidities of any type intermediate between maximum dryness or saturation are desired, it is possible to so control valves V1 and V2 that varying proportions of air pass through the water alone and through the sulphuric acid, mixing in jar B as they enter by 1 and 3 and leave by 2. It is to be noted that all air used passes through the washing jars as the first step in its treatment.

Three points concerning this apparatus must be mentioned: First, tests were run using indicators, which showed that there were practically no fumes of sulphuric-acid carried over that could have been suggested as a

factor contributing to the death of the bees. Second, the gauge of the Pitot tube was operated with water and in a manner permitting the recording of the low rates of air flow used in these experiments. To corroborate the methods used, check experiments were run on various rates of air flow, which confirmed the readings obtained by the method used. Third, the hair hygrometer was tested at intervals by wet and dry-bulb thermometer readings under varied conditions of temperature and humidity.

2. Experiments with Isolated Bees under Controlled Conditions.

During the course of the experiments described in this section, air was passed through the container at rates ranging between 5 and 12 liters per minute. The relative humidity is given for each group of experiments, along with the temperature in degrees centigrade. Reference to evaporation rates and relative humidity, as given for the various communities of the dune and morainic series and for prairie by Fuller (1914) (see Table VII this paper), reveals considerable variation between these communities. Fuller's data cover experiments during three seasons, each beginning early in May and running almost through October, though all of the communities were not tested throughout the entire season each year. As indicated in the table, the first part of it shows comparative results for the season, while the second part deals only with the ten weeks from the last of June until the first of Septem-

TABLE VII—Evaporation rate in certain plant communities as given by Fuller*

Section a. Mean weekly evaporation rates in cc. from a standard atmometer for three seasons under investigation

Association (Community)	1910	1911	1912	Average	Comparative rates
Cottonwood dune (I-3).....	21.1	24.6	21.3	22.3	319
Pine dune (I-4).....	11.3	10.3	9.7	10.4	149
Oak dune (I-5).....	10.3	11.8	10.9	11.0	157
Oak-hickory forest (I-6).....	.....	9.8	7.8	8.8	126
Beech-maple forest (I-7).....	8.1	7.4	5.6	7.0	100
Edaphic prairie (II).....	.....	12.5	12.5	12.5	179

Section b. Mean weekly evaporation rates in cc. from a standard atmometer during the 10 midsummer weeks of the three years under consideration

Association (Community)	1910	1911	1912	Average	Comparative rates
Cottonwood dune (I-3).....	25.0	30.2	20.3	25.2	315
Pine dune (I-4).....	14.1	12.6	10.3	12.3	154
Oak dune (I-5).....	12.1	13.4	10.1	11.9	149
Oak-hickory forest (I-6).....	.....	11.6	6.7	9.2	115
Beech-maple forest (I-7).....	10.2	8.5	5.3	8.0	100
Edaphic prairie (II).....	.....	15.1	12.4	13.7	171

*Section (a) is essentially Fuller (1914) Table I. Section (b) is essentially Fuller (1914) Table II.

ber. In the last column of each part of the table, the evaporation rate of beech-maple forest is assigned a value of 100, while the rates for the other communities are calculated from this, for purposes of comparison. It will be noted that cottonwood dune (I-3), pine dune (I-4), and oak dune (I-5) show higher rates of evaporation than do oak-hickory (I-6) and beech-maple (I-7), but that prairie (II) shows a high rate also.

The two sections of the table are included to show that the same general ratio between the different community evaporation rates holds, no matter whether the entire season be considered, or only the ten weeks from the last of June until the first of September.

TABLE VIII—*Averaged survival time and percentage of bees surviving for certain families and genera under conditions of controlled humidity and temperature**

Bees	41° and 25% or less		30° and 25% or less		30° and 60% approx.		41° and 85- 100%	
	mins.	% dead	mins.	% dead	mins.	% dead	mins.	% dead
Andrenidae.....	140	54.5%	...	.....	...	.....	...	.....
Colletidae.....	185	66.6%	...	.....	185	0.0%	...	.....
Chloralictus.....	49	66.6%	327	70.3%	54	0.0%	...	.....
					401	33.0%		
Other Halictidae.	63	73.5%	330	69.6%	354	22.0%	175	71.4%
					62	0.0%		
Calliopsis.....	177	85.7%	...	.....	172	0.0%	140	44.4%
					140	0.0%		
Prosopididae.....	70	71.4%	...	.....	70	0.0%	...	.....
Apidae.....	65	78.0%	278	75.0%	72	50.0%	...	.....
					317	83.0%		
Bombidae	145	65.4%	...	.....	300	0.0%	39	50.0%
(Bremidae)....					39	0.0%		
Ceratinidae.....	78	57.1%	508	71.4%	78	0.0%	68	100.0%
					288	50.0%		
Melissodes.....	86	75.0%	208	33.3%	74	50.0%	...	.....
					200	0.0%		
Megachilidae....	75	75.0%	563	0.0%	52	0.0%	...	.....
					563	100.0%		

*Centigrade temperature and relative humidity given.

Although the greater part of the readings included by Fuller were made at a height of 20-25 centimeters above the ground, it seems entirely permissible to use them as indicating general community conditions for purposes of comparison.

The experiments, described by the writer in this section, were designed to test the moisture conditions of the communities as possibly exerting a selective effect upon certain species or groups of bees. Bees apparently frequenting prairie should stand low relative humidity more successfully than should bees apparently frequenting the more moist, more humid communities. Otherwise the humidity-evaporation factor cannot be considered vital in attempting to work out bee distribution among the communities.

Table VIII gives averaged data by families and certain genera and is designed to indicate the effects of varying combinations of temperature and humidity upon the same classes of bees. The first set of conditions shows high temperature and low relative humidity. A glance at the table will show that these conditions were most severe. The second combination, with temperature around 30 degrees centigrade but with low relative humidity, reveals longer survival in every case where data are available. The third set of conditions represents, in reality, room conditions, and the data are in fact mostly drawn from controls. Two sets of data are given in a number of cases and it will readily be seen that the bees survived well in comparison with the first two experimental groups. The final column of data is the most incomplete and represents only four families of bees. However, it can be seen that these conditions are apparently more severe than the high temperature and low humidity for *Ceratinidae* and *Bombidae*, but are less severe for certain *Halictidae* and some bees of the genus *Calliopsis* of the *Panurgidae*. The *Halictidae* as a family show little tendency to restrict their visits to one type of plant community and the species of *Calliopsis* of the *Panurgidae* is also "general" in its distribution. The *Ceratinidae*, if anything, are found somewhat more commonly in dry conditions, while *Bremus vagans*, the species used in these experiments, apparently frequents the more humid regions, if any decision concerning its distribution is justified. This particular comparison thus offers only partial confirmation of the selective action of the physical factors under consideration.

At this point, it is necessary to call attention to the method of determining survival values for any experiment. Under ordinary conditions, the time of death of each specimen should be recorded and survival values calculated from these results. Under the conditions of the experiments described in this paper, it was necessary to lift the jar F from the bath P (Figure 1) quickly, in order to see if the specimens were dying. It had to be returned before cooling could take place, and it could not be opened and the bees taken out, or the entire conditions of the experiments would have been altered. Furthermore, a motionless bee, even with wings apparently set, would often prove to be alive and capable of revival. Hence it was necessary to wait until such time as a number of the bees were apparently dead, and then remove them and record the condition of each bee.

In Table IX, survival results under conditions of high temperature and low humidity are given for various species and sexes of bees. These bees were isolated individuals, used in comparison with groups of similar species in experiments to be described later (Section V C) and they had to be removed at times suitable for comparison with the grouped bees. Thus their survival percentages were controlled by the general experiment (the method is commented upon in the preceding paragraph), and it was not possible to

TABLE IX—Data of isolated bees from group-isolated individual experiments of Section V B. Survival time compared with type of habitat. 41° C. and 25 to 0% relative humidity

Bee	Assigned weight	Sex	No. of experiments	Total bees	% dead	Time out	Calc. mins. 100% dead	Habitat type
Clisodon terminalis.....	4	♀	1	1	100.0%	28	28	Moist (this region)
Apis mellifera.....	4	♀	8	41	78.0	62	79	General
Bremus americanorum....	2	♀	5	18	63.8	100	157	General
Bremus americanorum....	1	♀	1	3	83.3	462	554	General
Bremus americanorum....	2	♂	1	1	100.0	81	81	General
Bremus auricomus.....	2	♀	1	1	100.0	87	87	General (prairie)
Bremus bimaculatus.....	3	♂	1	1	100.0	116	116	Moist
Bremus fervidus.....	2	♀	3	3	0.0	140	....	Not Robertson
Bremus fervidus.....	3	♀	2	7	50.0	142	284	Not Robertson
Bremus fervidus.....	2	♂	1	1	0.0	120	....	Not Robertson
Bremus separatus.....	2	♀	3	10	50.0	96	193	General (prairie)
Bremus vagans.....	3	♀	7	39	81.1	80	98	Moist
Ceratina dupla.....	6	♀	3	14	53.5	78	145	General (prairie)
Melissodes agilis.....	5	♂	9	43	76.7	78	102	Dry (prairie)
Melissodes cnici.....	4	♂	1	4	25.0	126	504	Dry (decidedly prairie)
Melissodes simillima.....	5	♀	2	4	75.0	75	100	General (prairie)
Melissodes trinodis.....	4	♂	1	1	100.0	58	58	General (little dune-morainic)
Melissodes vernoniana....	4	♀	2	8	87.5	104	119	Dry (prairie)
Melissodes vernoniana....	5	♂	1	3	83.3	79	94	Dry (prairie)
Aleidamea simplex.....	6	♀	1	3	50.0%	40	80	General (prairie)
Osmia distincta.....	5	♀	1	6	91.6	78	85	General (red-white oak)
Osmia pumila.....	5	♀	2	4	88.5	59	66	Moist (flood-plain)
Sayapis sayi.....	4	♀	1	3	67.0	109	123	Dry (prairie)
Xanthosarus latimanus....	3	♀	1	1	100.0	70	70	Dry (prairie)
Parandrena andrenoides...	5	♀	1	1	87.5	289	330	General (moist)
Pterandrena aliciae.....	5	♀	2	8	62.5	102	163	General (no dune-morain.)
Colletes eulophi.....	5	♀	1	5	60.0	135	225	General
Colletes valida.....	4	♀	1	4	75.0	290	386	Dry (this region)
Agapostemon radiatus....	5	♀	1	3	83.3	79	94	General
Agapostemon viridulus....	5	♀	4	17	73.5	32	45	General (dry)
Chloralictus coeruleus....	6	♀	1	3	67.0	64	96	Moist
Chloralictus coeruleus....	6	♀	1	1	100.0	43	43	Moist
Chloralictus sparsus....	7	♀	1	4	75.0	45	60	General (flood-plain)
Chloralictus tegularis....	7	♀	2	3	87.5	43	49	General
Chloralictus versatus....	7	♀	6	26	67.7	47	70	Cosmopolitan
Chloralictus versatus....	7	♂	1	3	67.0	36	54	Cosmopolitan
Curtisapis coriacea.....	5	♀	1	7	71.4	39	54	Moist
Evylaeus arcuatus.....	7	♀	2	12	58.3	66	113	General
Evylaeus quadrimaculatus.	7	♀	1	1	100.0	65	65	General
Evylaeus quadrimaculatus.	7	♂	1	5	50.0	65	130	General
Evylaeus truncatus.....	7	♀	1	2	100.0	75	75	General
Odontalictus ligatus.....	6	♀	5	24	85.4	56	65	Dry (prairie)
Seladonia fasciata.....	6	♂	1	3	67.0	86	129	General
Calliopsis andreniformis...	6	♀	2	14	82.1	106	129	General
Prosopis ziziae.....	7	♀	1	7	78.6	70	90	General (dry)

record 100% mortality. To give us a basis of comparison between the different species and sexes, the time of 100% mortality has been calculated for each group, and the time value given affords some indication of the vitality of the bee under consideration. This was, of course, an arbitrary calculation and is presented only to facilitate comparison of survival and the most frequented type of habitat or community for the species. In Table IX, these characteristic habitat types or community types are given in the right-hand column as, for example, "moist" if the bee is apparently adapted to some habitat type, or "general" if no such adaptation is indicated.

In any experiments involving loss of water through evaporation by the animal being studied, the surface-mass ratio would be expected to exert a measurable effect, causing smaller bees to die more rapidly than larger bees. For this reason, the bees that are listed in the experiments described in Tables IX, XI, XIII, and XV are given values corresponding with size, the largest bee having the smallest value or "1," and the smallest bee being given the value "7." These values are approximations. Efforts to determine an exact set of values by weighing the bees were only partially successful. These values appear in the tables mentioned under columns marked "Assigned weight" but they were not considered in any way when determining assumed 100% mortality for the bees.

The descriptions of the habitat "tendencies" of the bees in Table IX may be placed in a series ranging from "moist" through "general with emphasis on moist," "general with emphasis in red-white oak," "general," "general with emphasis on prairie," "general with emphasis on dry," "dry with emphasis on prairie," "dry," and ending with "dry most strikingly prairie." These values are assigned to the bees mainly from study of the Robertson data as applied to Fuller's communities.

If now we summarize the data of Table IX into the habitat characterizations given above, and multiply each assumed 100% death value in minutes by a percentage equal to the "Assigned weight" value of the bee, the results can be compared in Table X.

Reference to the table shows the shortest survival under dry, hot conditions by bees which apparently would be expected to visit mostly conditions which we designate as "moist." The value 31.3 contrasts sharply with the values for "general" visitors which are supposed to visit dry regions or regions of high evaporation more than they do moist regions. These values are 48.2, 42.7, and 42.7. It will also be noted that bees described purely as "general" show a value of 55.4, which is higher than the "moist," "general dry," or "general prairie." This may be explained by crediting these wide-flying "general" visitors with greater all-round vitality and resistance to lethal conditions of all kinds. The last two values are indications of extreme resistance to dryness. "Dry," or 154.4, is given for *Colletes valida*, which was

taken on the dry sand along Lake Michigan, below Zion City, Illinois. These bees burrow 18 to 24 inches through hot, dry sand to build their nests. The second value given, for "general visitor with moist emphasized," 103.5, is far higher than consistency would warrant. However, this includes *Parandrena andrenoides*, a spring bee which has shown the habit of simulating death upon disturbance. It is conceivable that the dryness and heat act as disturbing stimuli which cause this bee to become motionless and reduce metabolism to a very minimum. It is inconceivable that death simulation should be accompanied by higher metabolic rate than that of the terrific vivacity of an active bee. This must still be tested, however.

TABLE X—Averaged survival values, weighted for bee size, compared by characterizations of the communities the bees most frequent*

Habitat type or characteristics of habitat or habitats frequented	Averaged weighted minute-value for bees considered	Number of sexes and species included	Number of bees included	Number of experiments included
Moist.....	31.3	7	56	14
General (moist emphasized).....	103.5	2	8	2
General (red-white oak emphasized) ..	42.5	1	6	1
General.....	55.4	17	149	37
General (prairie emphasized).....	48.2	5	32	10
General (dry regions emphasized).....	42.7	2	24	5
Dry (prairie emphasized).....	42.7	6	82	19
Dry.....	154.4	1	4	1
Dry (decidedly prairie).....	201.6	1	4	1
Total.....	.....	42	365	.....

*Data from Table IX. 41° C. and 25 to 0% relative humidity.

With study of the survival data of these bees by genera or families, and making no correction for size, it is observed that the males and workers of *Bremus* show a correlation in survival with habitat indicated: "moist" is 107 minutes, "general" is 119 minutes, and "general (prairie)" is 140 minutes. (Data averaged from Table IX.)

The five groups of data dealing with the family Megachilidae give "moist," 66 minutes; "general (red-white oak)," 85 minutes; "general (prairie)," 80 minutes; and "dry (prairie)," 96 minutes. This correlation is quite close when the wide variety of genera is recognized, *Alcidamea*, *Osmia*, *Sayapis*, and *Xanthosarus* being included.

Among the sexes and species of *Melissodes*, "general" has a value of 58 minutes; "general (prairie)," of 100; "dry (prairie)," of 105 minutes; and "dry (decidedly prairie)," of 504, due to the sturdy *Melissodes cnici*. This group gives perfect correlation.

In the Andrenidae, the long-lived *Parandrena andrenoides* outlived the fall *Pterandrena aliciae* 330 to 163 minutes, though the former is "general

(moist)" and the latter "general." *Parandrena andreoides* was mentioned above.

When reference is made to *Chloralictus*, the toleration data appear to show a negative correlation with habitat, "moist" being 69; "general (flood-plain)," 60; and "general," 58. However, these bees are so small that rapid drying out must in practice hide any physiological adaptation that might exist. If this explanation would not suffice, the death simulation of *Chloralictus* could be invoked to urge an uninterrupted activity on the part of the bees that visit both dry and moist environments, but a cessation of activity on the part of the moist-habitat bees when introduced into the unnatural dry conditions of the experiments. Given equal vitality, the difference in metabolism would explain the difference in survival time. I am inclined to favor the size explanation.

Among the remaining bees of the family *Halictidae*, the data do not correlate with the habitats. "Dry (prairie)" shows 65 minutes, "general (dry)" shows 45 minutes, "general" shows 101, and "moist" shows 54 minutes. Among the *Halictidae*, it would seem best to explain this lack of correlation with the habitat by the hardness and vigor of the "general" bees. In this group, as in the genus *Chloralictus*, however, small size with attendant rapid evaporation to a lethal point might act to mask any physiological adaptation.

The two species of *Colletes* considered are well correlated in survival with their habitats. *C. valida*, "dry," shows 356 minutes while *C. eulophi*, "general," is 225 minutes.

In Table XI are presented data of individual experiments with isolated bees, made separately from the experiments with groups and isolated bees reported in Table IX. In these experiments, a minimum and a maximum death value is given for each bee, which means that the bee was alive at the first time and dead at the second. For all values used, the mid-time is calculated. Weighing these data for bee size, as indicated in the table and as done in Table IX, we can summarize the values as shown in Table XII.

Among these experiments, bees with a "moist" habitat show the lowest survival value or 15.1, while "general" is only 15.5. The difference is much less than that between the same bee types of Table X, where the values are "moist" 31.3 and "general" 103.5. However, all the "more dry" habitats show higher values [though the "dry (prairie)" is only 20.5] with the exception of the last value, 9.6, which was obtained from a bee undoubtedly injured. Those of this species, *Melissodes cnic*i, gave very high values in the earlier table.

Thus it would seem that bees under experimental conditions of high temperature and low relative humidity show evidences of correlation in length of survival with conditions of the habitat which they most frequent.

But survival data taken from bees under conditions of approximately 30

TABLE XI—Survival tests of odd bees at 41° C. and 25 to 0% relative humidity

Bee	Assigned weight	Sex	Life Minimum Mins.	Mid Mins.	Life Maximum Mins.	Habitat most frequented
Clisodon terminalis. . . .	4	♂	17	24	31	Moist (this region)
Clisodon terminalis. . . .	4	♂	31	37	44	Moist (this region)
Bremus vagans.	3	♀	17	24	31	Moist
Bremus vagans.	3	♀	0	8	17	Moist
Melissodes bimaculata. .	4	♂	31	37	44	General (prairie)
Melissodes bimaculata. .	4	♀	100	100	100	General (prairie)
Melissodes bimaculata. .	4	♀	108	113	119	General (prairie)
Melissodes cnic.	4	♂	17	24	31	Dry (decidedly prairie)
Melissodes simillima. . .	5	♂	12	20	29	General (prairie)
Melissodes trinodis. . . .	4	♂	31	37	44	General (little dune-morainic)
Coelioxys sayi.	5	♂	82	82	82	General (dry)
Coelioxys sayi.	5	♂	98	103	108	General (dry)
Coelioxys sayi.	5	♂	0	4	9	General (dry)
Megachile generosa. . . .	5	♂	21	27	34	Dry (dune and prairie)
Sayapis pugnata.	4	♀	77	83	89	Dry
Sayapis sayi.	4	♂	108	113	119	Dry (prairie)
Sayapis sayi.	4	♂	66	72	79	Dry (prairie)
Xanthosarus latimanus. .	3	♀	22	27	33	Dry (prairie)
Xanthosarus latimanus. .	3	♀	22	27	33	Dry (prairie)
Xanthosarus latimanus. .	3	♀	33	45	58	Dry (prairie)
Pterandrena aliciae. . . .	5	♀	34	42	50	General (no dune-morain.)
Curtisapis coriacea. . . .	5	♀	22	27	33	Moist
Curtisapis coriacea. . . .	5	♀	33	45	58	Moist
Curtisapis coriacea. . . .	5	♂	66	72	79	Moist
Halictus lerouxii.	5	♀	12	20	29	General
Odontalictus ligatus . . .	6	♂	50	58	66	Dry (prairie)
Odontalictus ligatus . . .	6	♂	17	24	31	Dry (prairie)
Odontalictus ligatus . . .	6	♀	12	20	29	Dry (prairie)
Oxystoglossa confusa . .	6	♀	21	27	34	General

TABLE XII—Averaged survival values, weighted for bee size, compared by characterizations of the communities the bees most frequent*

Habitat type or characteristics of habitat or habitats frequented	Average weighted minute-value for bees considered	Number of bees
Moist.	15.1	7
General.	15.5	4
General (prairie).	27.5	4
General (dry).	31.5	3
Dry.	23.3	2
Dry (prairie).	20.5	8
Dry (decidedly prairie).	9.6	1
Total. . . . .	....	29

*Data from Table XI. 41° C. and 25 to 0% relative humidity.

TABLE XIII—Data of isolated bees from group-isolated individual experiments of Section V B.* Survival time compared with type of habitat

Bee	Assigned weight	Sex	No. of experiments	Total bees	% dead	Time out	Calc. mins. 100% dead	Habitat type
<i>Apis mellifera</i>	4	♀	6	40	75.0%	46	61	General
<i>Ceratina dupla</i>	6	♀	1	7	71.4	508	611	General (prairie)
<i>Melissodes vernoniana</i> ...	4	♀	2	9	33.3	200	600	Dry (prairie)
<i>Agapostemon viridulus</i>	5	♀	2	10	50.0	307	614	General (dry)
<i>Chloralictus sparsus</i>	7	♀	1	1	100.0	236	236	General (flood-plain)
<i>Chloralictus sparsus</i>	7	♂	1	6	83.3	742	890	General (flood-plain)
<i>Chloralictus versatus</i>	7	♀	1	6	66.6	236	354	Cosmopolitan
<i>Chloralictus vierecki</i>	7	♀	1	5	80.0	323	404	Dry (this area)
<i>Chloralictus zephyrus</i>	7	♀	2	6	66.6	137	205	General (moist)
<i>Curtisapis coriacea</i>	5	♀	1	5	60.0	307	510	Moist
<i>Dialictus anomalus</i>	7	♀	1	1	0.0	124	157	Dry (prairie)
<i>Evylaeus arcuatus</i>	7	♀	1	5	100.0	615	615	General
<i>Oxytroglossa confusa</i>	6	♂	1	3	100.0	116	116	General

*30° C. and 25 to 0% relative humidity.

TABLE XIV—Averaged survival values, weighted for bee size, compared by characterizations of the communities the bees most frequent*

Habitat type or characteristics of habitat or habitats frequented	Averaged weighted minute-value for bees considered	Number of sexes and species included	Number of bees included	Number of experiments included
Moist.....	255.0	1	5	1
General (moist).....	310.5	3	13	4
General.....	193.1	4	54	9
General (prairie).....	366.6	1	7	1
General (dry).....	307.0	1	10	2
Dry (prairie).....	174.9	2	10	3
Dry.....	282.8	1	5	1
Total.....	.....	13	104	.....

*Data from Table XIII. 30° C. and 25 to 0% relative humidity.

degrees centigrade and low relative humidity show little correlation with habitat conditions. There is the increased average length of survival which is to be expected. The data are presented in Table XIII, and the weighted, averaged values for the different habitats are given in Table XIV.

The majority of these experiments were with bees belonging to *Halictidae* in which group there was shown to be least correlation between survival time and habitat. These data would seem to indicate the difficulty of establishing any clean-cut correlation between survival and relative humidity of

the habitat of *Halictidae*, particularly where the temperature is not lethal in the experiments.

The specimens of *Apis mellifera* used here, in their behavior, indicate sensitivity to humidity on the part of these bees, to an unexpected degree. It will be seen that they died more rapidly than any others, and sufficient numbers of them were used to give a fair test. It must be noted, however, that this bee seems the least able of any species taken to endure laboratory experimental conditions.

Additional single records at 30 degrees centigrade and low relative humidity are available but offer no usable data except a general confirmation of longer survival if the temperature is reduced. These records are given in Table XV.

At a temperature of 30 degrees centigrade and with low relative humidity, it was observed that three males of *Oxystoglossa confusa* were dead in 116 minutes. The bee is predicted as "general." At the end of 732 minutes only 80% or four of another group of the same sex and species were dead when the temperature had been the same and the relative humidity had been 60%. Yet when the temperature was 33 degrees centigrade and the humidity was low, three females were all found to be dead in 58 minutes. If these bees were as adaptable as their flower-visiting habitats would indicate, no such variation of survival with humidity change should take place. Possibly there is no correlation between habitat and survival in this species of *Halictidae*.

Apis mellifera workers were indicated as "general" and showed low survival under conditions of either high or normal temperature and low relative humidity. But with temperature at 27 degrees centigrade and 85% or higher relative humidity, 85.7% of 7 isolated bees were still alive after 375 minutes. Another "general" bee with a differential survival!

Ceratina dupla, given as a "general" bee, with some emphasis on prairie visits, showed 53.5% survival among 14 bees after an hour and 18 minutes at 41 degrees centigrade and low relative humidity but showed 100% dead from a group of 3 after 1 hour and 8 minutes at 41 degrees centigrade and maximum relative humidity. This would seem to show a physiological correlation with a more dry environment.

Comparing three types of experiment using *Agapostemon viridulus*, given as "general" with emphasis on "dry" visits, we observe the following:

- (1) 4 exps., temp. 41°C., rel. hum. low, 17 bees, 73.5% dead, 32 mins.
- (2) 2 exps., temp. 30°C., rel. hum. low, 10 bees, 50.0% dead, 307 mins.
- (3) 1 exp., temp. 41°C., rel. hum. very high, 5 bees, 80.0% dead, 211 mins.

According to the survival data, this bee would seem to be adapted to moist conditions, although the observational data and our predictions would make it "general" or with a tendency toward dry conditions.

Calliopsis andreniformis is given as a bee visiting all habitats. But with 41 degrees centigrade and low relative humidity, 82.1% of 14 bees were dead in 106 minutes, while with the same temperature and with the relative humidity at maximum, all of a set of 5 isolated bees were still alive after 140 minutes. But the above were all females. Four males at that temperature and with high humidity were all dead in 140 minutes. Apparently a variation in resistance of the sexes is indicated.

Bremus vagans is given as a bee frequenting moist habitats. Using 41 degrees centigrade as the temperature in all cases, we observe that of 39 specimens under very dry conditions, 81.1% were dead in 80 minutes. Yet with relative humidity practically at saturation, with 8 bees used, 50.0% were dead in 39 minutes. This again would not be evidence in favor of a correlation between conditions of habitats most frequented and maximum experimental survival conditions.

TABLE XV—Survival tests of odd bees at 30° C. and 25 to 0% relative humidity

Bee	Assigned weight	Sex	Life Minimum Mins.	Mid Mins.	Life Maximum Mins.	Habitat most frequented
Melissodes bimaculata.	4	♀	0	27	55	General (Prairie)
Megachile generosa....	5	♂	55	167	280	Dry (dune and prairie)
Megachile generosa....	5	♂	55	167	280	Dry (dune and prairie)
Megachile generosa....	5	♂	55	167	280	Dry (dune and prairie)
Megachile mendica....	4	♀	55	167	280	General (cosmopolitan)
Sayapis pugnata.....	4	♀	176	182	189	Dry
Sayapis pugnata.....	4	♀	189	201	214	Dry
Sayapis pugnata.....	4	♀	189	201	214	Dry
Sayapis sayi.....	4	♂	238	...	...	Dry (prairie)
Xanthosarus latimanus.	3	♂	208	223	238	Dry (prairie)
Xanthosarus latimanus.	3	♂	238	...	...	Dry (prairie)
Xanthosarus latimanus.	3	♀	0	7	15	Dry (prairie)
Evylaeus arcuatus.....	7	♀	114	130	147	General
Evylaeus arcuatus.....	7	♀	114	130	147	General
Evylaeus arcuatus.....	7	♀	290	...	...	General
Evylaeus arcuatus.....	7	♀	290	...	...	General
Evylaeus arcuatus.....	7	♀	147	163	180	General
Evylaeus arcuatus.....	7	♀	223	256	290	General
Evylaeus truncatus....	7	♀	114	130	147	General
Evylaeus truncatus....	7	♀	147	163	180	General

3. Factors Influencing Experimental Results.

During the course of the description of experiments, it has been necessary to mention several influencing or qualifying factors. The simulation of death is one factor that may be disputed. I have observed it so frequently among the *Halictidae* and the *Andrenidae* that the only question need be its efficacy in the present instance. This would depend upon duration of the simulation period. In the case of a mechanical shock such as is responsible most often for inducing the reaction, it was observed that if the shock be re-

peated at intervals, there was some but very little adjustment to it. Successive periods of inactivity apparently became somewhat shorter, but really very little shorter. Whether heat and low humidity could serve as the same stimulus as a mechanical shock is questionable. The nature of the constant temperature bath, in which the bees were immersed in their container, was such that all direct light was eliminated and upon removal the emergence into bright light usually served to stir up the more active bees. It would scarcely seem justifiable to assign more than a few moments to the death-simulation factor as effective in quieting *Halictidae*.

That the high temperature and low humidity exerted a far more rapid lethal effect on small bees than on large bees was evident. Often great difficulty was experienced in pinning *Chloralictus* or *Prosopis* specimens that had been killed at high temperature and low relative humidity. They are both small bees and they would actually be brittle in a surprisingly short time. It was usually possible to estimate which bee died first in some of the experiments with groups, reported in the next section. The longer the bee had been dead, the more the difficulty that was experienced in pinning it.

Size of individual containers for the bees was shown to have an effect. This will be discussed later.

One factor that came up before the experiments were undertaken must now be mentioned. With recent work that has been done concerning animal aggregations in mind, the question was raised whether one was justified in treating experiments with isolated individuals of social and semi-social bees in the same manner as one would treat such experiments with solitary or non-social bees. It was decided to test this question along with the survival data. Justification of the methods used in the experiments given in this section is made in the following section, devoted to comparison of reactions of groups and isolated individuals of different bees.

4. Conclusion.

In concluding this section, I would say that there is evidence that certain species of bees tend to visit certain environments or plant community types to an excess over other communities, such that they can be deemed adapted to these communities. It would seem that, in certain of these instances, the fundamental adaptation has been one of the bee to the flowers of those communities, but there is no evidence to prove that the flower adaptation may not be the one which is secondary.

Furthermore, it would seem that certain of these bees which are not apparently more frequent visitors to one community than to another, and which are found in several habitats with all types of relative humidity and with varying evaporation rates, are the more hardy bees and can stand, for longer periods, extremes of temperature or relative humidity. On the other hand, there is evidence that certain species and groups of bees are very definitely

correlated in physiological make-up with the physical conditions of certain plant communities, so much so that, for example, they show more ability to endure dry conditions if they are bees that visit dry communities more often than moist. Conversely, those visiting moist more than dry have less ability to withstand dry conditions. Certain supposedly "general" bees under experimental conditions show an adaptation to one or the other extreme of humidity. (See experiments given later, dealing with groups and isolated individuals.)

The smaller the bee, the less its adjustment, and the less chance of testing such adjustment as it may have.

V. TESTING TOLERATION DATA BY EXPERIMENTS WITH GROUPED AND ISOLATED BEES

A. ANIMAL AGGREGATIONS STUDIES AND THEIR IMPLICATIONS WITH RESPECT TO THE BEE EXPERIMENTS

A complete study of the subject of Animal Aggregations, together with a very complete survey of the literature, is given by Allee (1931). The bees rank as most interesting material for such studies, exhibiting as they do various degrees of aggregation in different families, genera, and species, from the most solitary species of inquiline to the perfect colony of *Apis*.

Doubtless several factors have been responsible for the evolution of the well-developed social organization to be seen in the hive bee or even in the *Bremidae*. The development of the specialized worker class is in all probability a product of this colonial organization and is not one of the factors in its formation.

Just as other more simple animal groupings have come under intensified scrutiny in search of these factors which have been responsible for the aggregating of the individuals composing them, so it should be possible to determine the causes of bee colony evolution. And just as the advantages to be gained by individuals of a simple aggregation of animals have been most carefully sought, so it should be possible to determine the advantages to be gained by aggregations of a more complex nature, such as are exemplified by the colonies of *Apis*, *Bremus*, *Trigona*, and *Melipona*.

Comparisons of reactions of these colonial forms of bees with reactions under similar conditions by bee species of lower colonial or social organization, or with bees having essentially no tendency toward aggregation, when both groups are exposed to various controlled conditions, should throw some light on the influence of those factors or upon the physiological adaptations of the solitary and social bees to solitary or social life.

The following sections offer some clues toward an eventual solution of the causes and advantages of social organization among the bees, treating

though they do only of heat and humidity, with no discussion of the more general social problems (such as those which center about food, for example) and all of their ramifications into the field of "the division of labor."

B. IS THERE A DIFFERENTIAL TOLERATION BETWEEN GROUPED AND ISOLATED BEES DEPENDING UPON THE DEGREE OF SOCIABILITY OF THE SPECIES UNDER CONSIDERATION?

Consideration of the general work in the Aggregations field, described by Allee (1931) in connection with the various degrees of colonial integration shown by the bees as a super-family, raises a rather interesting question, which is given as the heading for this section, with regard to bee survival under lethal conditions.

This question can be best discussed by citing certain experimental conditions and then discussing possible results that might be expected from experiments run under those conditions.

If we assume the presence of the lethal conditions of high temperature and low relative humidity, our discussion will center about the humidity factor, the bees being assumed to have little control, under experimental conditions, of the temperature factor which we introduce merely to shorten the life-period for all species under experimentation.

Social or semi-social bees, introduced into these lethal conditions and in vials of what we may call "medium" size with both ends open, permitting free air flow, are placed in groups and are isolated. If five bees form the group, five isolated bees occupy five vials of similar size under identical conditions. The bees of the group, due to their social behavior patterns, might then be expected to attempt to block the flow of dry air through the container, by massing in an effective manner. The isolated bees, thrown upon their own resources and with no aid from other individuals, are unable to simulate the moist conditions of the nest or even to approach those conditions and soon lose water to a lethal point, usually much earlier than the individuals of the group. Furthermore, we may assume that the grouped bees find themselves in a normal environment, as far as the presence of their fellows is concerned, and are hence inclined to become quiet after completing the partial blocking of the air flow. The isolated social or semi-social bee has the further adverse stimulus of being separated from its fellows and may be moved to tremendously exhausting efforts.

It is conceivable, of course, that if the ratio between bee size and vial size is too great in the case of the grouped bees, they will be unable to block the air flow and will continue vain activity in this direction with a resulting diminution of the remaining period of life of each bee. In this case, the isolated bees might even be expected to outlive the grouped bees.

Conversely, if the bees of the group are placed in a vial which is too small,

they will tend to suffocate and the isolated specimens would be expected to outlive the group. Here too the physical factors would completely mask any social behavior patterns, as far as results are concerned.

If we now consider similar experiments with non-social or solitary bees, we may assume that a group of them, placed in the same vial, will exhibit no concerted effort to gain control of the environment. They will naturally profit from the surface-mass ratio in comparison with the isolated bees and will lose less water per bee merely from being together in the one vial. But on the other side, they will often be stimulated to violent activity when they come into contact with each other, as was continually observed in the cases of such bees being brought in from the field, in groups, in vials. The isolated bees may soon settle down to general inactivity, which observation alone, in the case of bees, is capable of assuring us must mean lower metabolic rate than the terrific activity of a bee under some adverse stimulus. Thus the isolated solitary bees may be expected to actually outlive the groups about as often as the groups of bees outlive them.

It might be well to visualize suggested effects of the experimental physical conditions upon the bees in the following manner: Let us assign a value of 7 arbitrarily to any bee which is permitted to live in theoretical, controlled conditions, uninfluenced by physical conditions or presence or absence of other bees. This 7 represents what we may call "remaining life expectancy." Now let us designate social or semi-social bees with "S" and non-social bees with "N." And let us designate bees of any kind in groups as "G" and isolated bees of any kind as "I." Now let us arbitrarily indicate two adverse stimuli: the one the effect of the dry air, which we can designate as 2; the other any adverse stimulus from the presence or absence of other bees, which we may designate as 1. On the other hand, we may designate as 1 the advantage to be gained from the mere physical presence of a group, due to the surface-mass effect.

Then we have "SG" 7, less 2 (air), plus 1 (group effect), and the result is "SG" 6.

And we have "SI" 7, less 2 (air), less 1 (absence of others), and the result is "SI" 4. Which means that if we have a group effect and a social effect the grouped social bees will outlive the isolated ones.

Then too we have "NG" 7, less 2 (air), plus 1 (group effect), less 1 (presence of others), and the result is "NG" 5.

And we have "NI" 7, less 2 (air), and the result is "NI" 5. Which would mean that we might obtain no definite result in either direction as far as experiments with groups and isolated non-social bees are concerned.

C. SURVIVAL EXPERIMENTS CONTRASTING GROUPS AND ISOLATED BEES

Using the apparatus described in Section IV C 1 d, experiments were run with intent to compare the survival of grouped and isolated bees of various

species. In so far as possible, the attempt was made to use bees of the same species in a given experiment. Occasionally later study proved that two or more species and even sexes had been used. In certain cases it was known that more than one species, or caste, or sex were being used. In these cases, bees of the different kinds were as far as possible equally distributed between the groups and the isolated individuals.

As indicated in Section V B, the writer must confess to having had certain definite ideas concerning the manner in which the survivals would work out before the experiments were run. Thus it was believed that possibly the groups of *Apis mellifera* would outlive the isolated bees, and it was deemed possible that this would hold for the *Bremidae*. As a consequence, where any choice was possible between individual bees of the same species, the stronger or more active individuals were placed where conceivably they would live the shortest time. This may have had some slight influence on the general results, although it has been found by these experiments that observation of activity and apparent vitality is a very poor index of longevity or survival.

Over 1,350 bees were used in these experiments and as controls. Only part of these are here reported.

TABLE XVI—Comparative survival time of grouped and isolated *Apis**

Exp. No.	Time		Group			Isolated bees			Survival of group over isolated bees
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
13.....	1	2	5	5	0	5	4	1	-1
16.....	1	2	7	4	3	7	7	0	3
69.....	..	57	5	0	5	5	5	0	5
70.....	1	33	5	3	2	5	5	0	2
74.....	..	39	4	2	2	4	4	0	2
80.....	..	28	5	0	5	5	1	4	1
82.....	1	23	5	0	5	5	3	2	3
84.....	1	35	5	4	1	5	3	2	-1
Total.....	..	..	41	..	..	41	..	..	14

By Student's method of testing for significance there are 468 chances in 10,000 of random sampling giving the same result.

*Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12, vials 1.8 cms. diameter inside by 5 to 6.5 cms. long, designated as "medium."

The results presented in Table XVI are from experiments with workers of *Apis mellifera*, which were exposed to a temperature of 41°C., and 25 to 0% relative humidity, in vials open at both ends but screened, vial dimensions 1.8 cms. inside diameter and 5 to 6.5 cms. long.

The first experiments using *Bremus* (*Bombus*) gave results favoring the isolated bees. The conditions of the experiments were essentially similar to those in the preceding table. The results are given in Table XVIIa. Larger containers were then used, and the results were shown to be more favorable to the grouped bees (see Table XVIIb for these data). The vial size in the

second group of experiments with *Bremus* was increased to 4.5 cms. in diameter and 6.0 cms. long. Since this genus is made up of bees averaging much larger in size than *Apis*, it was obvious that the grouped bees might well be smothering in the small vials.

TABLE XVII—Comparative survival time of grouped and isolated specimens of *Bremus*

Section a. "Medium"-sized vials*									
Exp. No.	Time		Group			Isolated bees			Survival of isolated bees over group
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
3.....	8	4	3	3	0	3	2	1	1
54.....	2	0	8	8	0	8	4	4	4
59.....	1	21	5	4	1	6	3	3	2
65.....	1	56	6	5	1	6	5	1	0
75.....	2	29	5	1	4	5	2	3	-1
76.....	2	29	3	2	1	3	1	2	1
Total.....	..	..	30	..	..	30	..	..	7

By Student's method of testing for significance there are 1602 chances in 10,000 of random sampling giving the same result.

Section b. "Large"-sized vials†									
Exp. No.	Time		Group			Isolated bees			Survival of group over isolated bees
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
96.....	2	6	5	3	2	5	5	0	2
98.....	2	6	5	4	1	5	4	1	0
100.....	1	1	5	2	3	5	4	1	2
101.....	2	10	5	4	1	5	5	0	1
105.....	2	0	5	1	4	5	4	1	3
106.....	1	27	5	4	1	5	3	2	-1
110.....	3	16	5	2	3	5	2	3	0
111.....	2	0	5	2	3	5	2	3	0
112.....	1	55	5	2	3	5	4	1	2
113.....	2	25	5	3	2	5	3	2	0
Total.....	..	..	50	..	..	50	..	..	9

By Student's method of testing for significance there are 244 chances in 10,000 of random sampling giving the same result.

*Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12, vials 1.8 cms. diameter inside by 5 to 6.5 cms. long, designated as "medium."
†Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12, vials 4.5 cms. inside diameter by 6.0 cms. long, designated as "large."

The first experiments with *Chloralictus* were tested in "medium"-sized vials and gave results favoring the isolated bees, as shown in Table XVIIIa. Inasmuch as experiments with others of the *Halictidae* favored the grouped bees, these results were unexpected. A change to smaller vials was made and the results when vials .4 cms. in diameter by 4.0 cms. long were used are shown in Table XVIIIb, favoring the groups. The small bees of the group

were apparently unable to gain control of the vial if it was too large. When the size of the vial was reduced, they were able to exert a combined effort and lessen the harmful effects of the environment.

TABLE XVIII—Comparative survival time of grouped and isolated *Chloralictus*

Section a. "Medium"-sized vials*									
Exp. No.	Time		Group			Isolated bees			Survival of isolated bees over group
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
7.....	1	20	4	4	0	4	4	0	0
8.....	..	23	6	3	3	6	2	4	1
12.....	..	45	5	3	2	5	3	2	0
35.....	..	49	4	4	0	4	4	0	0
38.....	..	36	3	3	0	3	2	1	1
39.....	..	48	5	4	1	5	5	0	-1
57.....	1	4	3	0	3	3	2	1	-2
85†.....	1	5	5	5	0	5	1	4	4
Total.....	..	..	35	..	..	35	..	..	3

By Student's method of testing for significance there are 5674 chances in 10,000 of random sampling giving the same result.

Section b. "Small"-sized vials**									
Exp. No.	Time		Group			Isolated bees			Survival of groups over isolated bees
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
99.....	..	52	4	2	2	4	2	2	0
102.....	..	43	5	3	2	5	5	0	2
103††.....	1	5	5	3	2	5	4	1	1
104.....	..	35	4	1	3	4	3	1	2
107.....	..	50	5	4	1	5	3	2	-1
108.....	..	41	5	3	2	5	4	1	1
109.....	..	40	4	3	1	4	2	1	0
Total.....	..	..	32	..	..	32	..	..	5

By Student's method of testing for significance there are 1422 chances in 10,000 of random sampling giving the same result.

*Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12.
†Some bees of experiment 85 were small species of *Evylaeus*, a related genus.
**Conditions the same as in Section (a), but the vials .4 cms. diameter by 4.0 cms. long.
††Some bees of experiment 103 were small species of *Evylaeus*, a related genus.

Studies on species of the larger genera of Halictidae such as *Odontalictus* and *Evylaeus* gave a striking difference in survival of grouped individuals compared with isolated individuals (see Table XIX). The physical conditions of the experiments were the same as in those previously reported, and the "medium"-sized vials were used.

The *Halictidae*, which of course include *Chloralictus*, may be considered semi-social bees, though there are certain notable exceptions. If they are considered as semi-social, then it is to be seen that the above data would indicate that they are reacting in a manner similar to that of the truly social *Apidae* and *Bremidae* (*Bombidae*), and are showing group survival for longer periods than the survival of isolated bees under conditions otherwise similar.

A number of experiments were tested at room temperature, approximately 30 degrees centigrade and 20 to 0% relative humidity. Only with *Apis mellifera* were there sufficient cases to record, and they again showed a higher group survival, as reported in Table XX.

TABLE XIX—Comparative survival time of grouped and isolated specimens of genera of *Halictidae*, no specimens of *Chloralictus* included*

Exp. No.	Time		Group			Isolated bees			Survival of groups over isolated bees
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
4.....	1	40	4	1	3	4	4	0	3
5.....	1	19	3	1	2	3	2	1	1
6.....	1	26	3	0	3	3	1	2	1
10.....	..	39	7	1	6	7	4	3	3
14.....	..	55	4	2	2	4	4	0	2
15.....	..	30	4	2	2	4	4	0	2
18.....	..	57	7	2	5	7	4	3	2
30.....	..	38	2	1	1	2	2	0	1
32.....	1	24	7	4	3	7	6	1	2
34.....	1	15	7	3	4	7	3	4	0
55.....	..	50	7	5	2	7	5	2	0
56.....	1	4	3	1	2	3	3	0	2
66.....	..	55	5	2	3	5	5	0	3
67.....	1	12	5	5	0	5	3	2	-2
Total.....	..	..	68	..	..	68	..	..	20

By Student's method of testing for significance there are 22 chances in 10,000 of random sampling giving the same result.

*Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12, vials 1.8 cms. inside diameter by 5.0 to 6.5 cms. long, designated as "medium."

Study of Tables XVI to XX indicates that, if the proper vial-size bee-size ratio is determined upon, groups of social or semi-social bees will outlive isolated specimens. Tables XVIIa and XVIIIa both give data with bees tested in the medium-sized vials which were found successful for *Apis* and *Halictidae* other than *Chloralictus*. These vials evidently proved too large for specimens of *Chloralictus* to control, and too small for *Bremus*. As shown in the Tables XVIIa and XVIIIa, the isolated bees outlived the grouped bees in these tests. However, when the vial size was decreased for *Chloralictus*, as reported in Table XVIIIb, results favored the grouped bees. When the size of the containers was enlarged for *Bremus*, the group outlived the isolated bees, as shown in Table XVIIIb.

TABLE XX—Comparative survival time of grouped and isolated specimens of *Apis**

Exp. No.	Time		Group			Isolated bees			Survival of groups over isolated bees
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
40.....	3	40	7	1	6	7	2	5	1
44.....	5	35	7	5	2	7	6	1	1
48.....	6	36	7	4	3	7	7	0	3
49.....	7	5	7	2	5	7	5	2	3
51.....	3	45	7	5	2	7	6	1	1
52.....	1	10	5	2	3	5	4	1	2
Total.....	..	..	40	..	..	40	..	..	11

By Student's method of testing for significance there are 60 chances in 10,000 of random sampling giving the same result.

*Temperature approximately 30° C., relative humidity 20 to 0%, air liters per minute 5 to 12, vials 1.8 cms. inside diameter by 5 to 6.5 cms. long, designated as "medium."

The data given in Tables XVI to XX confirm the suggestions advanced in Section V B concerning the behavior of social or semi-social bees under experimental lethal conditions of temperature and humidity.

In contrast with the experiments described in the preceding Tables XVI to XX, inclusive, which deal with social and semi-social bees, Table XXI presents data obtained from experiments with solitary bees of the family *Euceridae*, genus *Melissodes*. These experiments were carried on with the bees in vials 1.8 cms. in diameter and 5 to 6.5 cms. long. They were maintained at a temperature of 41°C., and 25 to 0% relative humidity.

Inspection of the data given in Table XXI indicates that the grouped and isolated bees have approximately the same survival time. However, the ex-

TABLE XXI—Comparative survival time of grouped and isolated *Melissodes**

Exp. No.	Time		Group			Isolated bees			Survival of isolated bees over groups
	Hr.	Min.	Total	Dead	Alive	Total	Dead	Alive	
26.....	1	11	2	1	1	2	1	1	0
28.....	2	38	3	2	1	3	2	1	0
29.....	1	19	5	3	2	5	3	2	0
33.....	1	10	5	4	1	5	4	1	0
87.....	1	39	5	4	1	5	4	1	0
88.....	1	39	5	5	0	5	4	1	1
89.....	1	39	5	4	1	5	5	0	-1
90.....	1	12	5	3	2	5	2	3	1
91.....	1	12	5	4	1	5	5	0	-1
92.....	1	12	5	3	2	5	5	0	-2
93.....	1	5	5	5	0	5	5	0	0
94.....	1	5	5	4	1	5	3	2	1
95.....	1	5	5	3	2	5	4	1	-1
97.....	2	6	4	3	1	4	1	3	2
Total.....	..	..	64	..	..	64	..	..	0

*Temperature 41° C., relative humidity 25 to 0%, air liters per minute 5 to 12, vials 1.8 cms. diameter inside by 5 to 6.5 cms. long, designated as "medium."

periments were not as complete as those reported in Tables XVI to XX which give results obtained from social and semi-social bees. Only one vial size, that one designated as "medium," was used. It would possibly be desirable to test these solitary bees in vials of other sizes. However, "medium" vials were used with the *Apis* and statistically significant results were obtained, as shown in Tables XVI and XX. *Melissodes* should have experienced no difficulty, when placed in groups in these vials, that *Apis* would not have experienced, for the bees are of approximately the same size, both groups having been given an "assigned weight value" of 4, as shown in Table IX, for example.

A study of the data in Tables XVI to XX, inclusive, would seem to indicate that there is some foundation for the belief that social or semi-social bees have developed an adaptation to group existence which acts as an advantage when groups are placed under adverse conditions. If these general results can be shown to hold for all kinds of bees, non-social as well as semi-social and social, then a physical explanation can be sought and one is easily found. The mere physical presence of several bees in one container will reduce the rate of evaporation from each bee, and will permit the bees of the group to live for a longer time, before sufficient water is evaporated from them to cause death, than would be the case with the isolated bees.

However, such a simple mass relation is not the only possibility. Preliminary observations indicate that there is a difference in activity of grouped and isolated social or semi-social bees from that shown by grouped and isolated solitary bees under similar conditions of confinement in relatively small space; that groups of social bees tend to be relatively more quiet when in vials than are isolated individuals, while the opposite relation holds with bees belonging to solitary species. Some such differences in behavior are to be expected and further critical experiments may demonstrate that such behavior differences are mirrored in the toleration of adverse experimental conditions by grouped and isolated bees, as suggested in the previous section. The data at hand have allowed us to recognize the problem and to indicate the method whereby its solution may be attempted.

D. EXPERIMENTS WITH GROUPS AND ISOLATED BEES INDICATE THAT SURVIVAL RESULTS GIVEN IN SECTION IV C HAVE BEEN AFFECTED BY INCLUDING SOCIAL, SEMI-SOCIAL AND NON-SOCIAL BEES IN THE SAME MASS OF EXPERIMENTAL DATA

Toleration experiments with groups and isolated social and semi-social bees of the families *Apidae*, *Bremidae*, and *Halictidae*, and with the non-social bees of the family *Euceridae*, indicated a shortening of the expected life-period of any isolated bee of the first three families, while less varied experiments were inconclusive with those bees of the *Euceridae*. If the im-

perfect results at hand have value, it must therefore be noted that survival data obtained by the study of isolated bees, as reported in Section IV, have been thrown open to question by having included social, semi-social, and non-social bees in the same tables for comparisons. However, these data have been rendered incorrect for comparison only in so far as it can be shown that, for example, solitary species of Euceridae have been included as more or less than half of the cases where “dry” habitat bees are compared as to survival under dry conditions with “moist” habitat bees, while social species of *Bremidae*, which would count isolation from their fellows as an additional lethal factor, form less or more than half the cases where “moist” habitat bees are compared as to survival under dry conditions with “dry” adapted bees. If half the cases of “dry” adapted bees are social or semi-social with the other half non-social, while the same holds true for the “moist” adapted contrasted cases, then the data are altered on both sides and no harm is done.

Referring to Tables IX and XI, which give the data concerning experiments with isolated bees, described in Section IV, we observe that under conditions of high temperature and low humidity the following numbers of bee species and sexes were used, and these bees were characteristically found in the types of environment given (see Table XXII).

Inspection of the summary of the kinds of bees used (Table XXII) in the experiments with isolated individuals, reveals the fact that the majority

TABLE XXII—Numbers of species and sexes of social-semi-social and of non-social bees found to frequent certain habitats and used in toleration experiments as isolated bees

Bee Types	Experiments with Groups and Isolated Bees				Odd Experiments with Isolated Bees				Total
	Habitat			Total	Habitat			Total	
	Moist	General	Dry		Moist	General	Dry		
Social or Semi-social....	6	13	4	23	5	2	3	10	33
Non-social.....	3	5	11	19	2	2	15	19	38
Total.....	9	18	15	42	7	4	18	29	71

of the social or semi-social bees used were considered as being either “general” or “moist” in their habitat distribution, while the majority of non-social bees used come under a “dry” category. These points not only show that the data with isolated bees of Section IV C have been affected if later experiments should prove that non-social bees tend to live longer when isolated, while social and semi-social bees tend to have their life period shortened when isolated, but also raise the question whether social and semi-social bees may not be more widespread in distribution (throughout the year as well as throughout various habitats), and thus in reality be the more vigorous and resistant of the bees.

The three families mentioned, *Apidae*, *Bremidae*, and *Halictidae*, including the social and semi-social bees, do fly, as suggested above, from early in the spring until late in the fall. Not all species and not all sexes will be on the wing, but the majority of the species can be collected as worker or female as long as flowers are in bloom and the weather is good. The non-socials, on the contrary, have definite flight-periods which are mostly short. Seasonal variations in humidity and temperature thus present opportunity for other possible correlations with the physiology of these bee species.

The social and semi-social bees must spend a considerable portion of their time in the nest with other bees, where the humidity must be assumed to be high. From this region of safety and comfort, the bees wing out, periodically, into all environments or habitats, collecting and working as they will, losing water in the dry regions, but able to return to the nest long before the water loss becomes serious or lethal. Perhaps, then, we can say that they are not only possibly more resistant, but are also in reality "moist" adapted bees, though their flower visits would place the majority of them as "general" in distribution, according to our classification as given in Table XXII and earlier tables.

Now comparing the non-social bees, we find them emerging from their cells when the pupal stage is over, and flying to their flowers or to their plant communities, but making no effort to return to a communal nest having constant temperature and humidity, even though they may all build nests in the same general locality. If adapted to dry conditions, they visit dry habitats mainly, and even may build their nests in these regions. (It is recognized, of course, that in dry regions any bee will tunnel through sand or clay or wood to reach some moisture for the nest, if this is possible.) If adapted to moist regions, the bees will tend to remain in this type of environment. In the case of oligoleges we have reasons for assuming that they nest near their flower-food sources.

The general suggestion of social and semi-social bee adaptation to moisture depends upon the proof of the high humidity of the nest. Most persons will doubtless grant the assumption for *Apidae* and *Bremidae*. The survival data for *Apidae* exposed to high temperature and high humidity (Table XX) compared with survival at low humidity (Table XVI) will go a long way in the establishment of this premise. But few will be willing to concede that the majority of the *Halictidae*, with their tunnels and branches, have a nest that is maintained at high humidity. In this connection, let me suggest that the female Halictid whom every entomologist has seen at the common-gallery entrance with head fitting snugly in the passage and facing outward is not there only to guard against intruders, but may also be serving instinctively or otherwise as a door to keep the moisture inside, on warm dry days. If she were a sentinel only, it is inconceivable that she should allow the parasitic *Sphecodes* to enter and lay her eggs.

The data obtained from experiments carried on with groups and isolated individuals probably have little effect toward altering any decisions concerning the correlation between bee-survival and habitat-conditions. It was stated in Section IV that certain bees apparently were adapted and others were not. It was pointed out that *Halictidae* apparently showed no correlation. If they are mesic or "moist," as assumed because most of them are semi-social, this lack of correlation is explained. The apparent correlation, of *Bremidae* survival with environment, required omitting the data available from *Bremus americanorum* females and may have been due to chance. It will be noted that all of the bees involved are given a "general" distribution and only *Bremus separatus* is shown as having emphasis on prairie visits.

VI. CONCLUSION

During two seasons it has been possible to collect specimens of at least one sex of over half of the species of bees to be found within a radius of seventy-five miles of Chicago. This has been accomplished with little collecting in the dunes regions and with major emphasis placed on morainic oak and semi-climax, flood-plain, and prairie. Weeds and ruderals, old fields and orchards, have not been disdained. It will require several additional seasons to cover all communities at all necessary times of the year.

With these species, given mainly according to the terminology of Robertson, it has been possible to cite either the original record of description of the bee, or else a better description has been added, or at least a key record which will remove the bee from the category of being only a name.

Comparison of the bee-flower relationships, given by Robertson (1928), with the flower-community data of Fuller (1925) and Pepon (1927) (Appendix B) and local bee collection data, indicates that it is fair to assume that the bees and flowers known to have definite relationships in the Carlinville area can be expected to maintain the same general relationships if both the bee and the flower occur in the Chicago area. From these data, it is even possible to predict bee visitors and communities visited in the dunes series. The extent to which this is only a prediction is quite evident to the reader and confirmatory or corrective evidence is much to be desired.

From Robertson's data, it has been possible to indicate local plant communities which certain bee species will be expected to visit more frequently than other communities. From these data, it has been possible to assign certain environmental characteristics as being the ones most frequented by given bees. Even without collecting in the dunes regions, Robertson's data offer interesting correlations of species peaks of certain families in certain communities of the dunes sere. Tables III and IV should be compared with Park (1930). Study of these tables indicates that the more flowering plants in a given community, the fewer bees will visit each plant. Predictions from

Robertson's data range from 17.3 bees per flower in the tamarack stage of the peat bog community, to 1.85 bees per flower in the flood-plain community.

Bees have been classified according to the physical characteristics of the communities they visit most frequently. Certain bees have been characterized as "general,"—that is, visiting all communities with about equal frequency; "dry,"—that is, "preferring" or visiting the communities where humidity is lower or rate of evaporation is higher; and so on.

Large numbers of the bees have been brought back alive to the laboratory and tested under controlled conditions of constant humidity and temperature. These experiments have shown that high temperature (41°C.) exerted a decidedly lethal effect upon all species of bees tested. They also showed that low relative humidity (25% or lower) exerted a less noticeable lethal effect, more variable from species to species. Extremely high relative humidity (over 85%) was also shown to exert a lethal effect, though fewer experiments of this nature were made than with the other conditions.

These experiments indicated that there was a general correlation between rapidity of lethal effect of low humidity and smallness of bee size. But they also showed that, in cases of low humidity and high temperature, there was a definite correlation (when all the kinds of bees used were weighted for size and averaged) between survival time and character of habitat most frequented by the bees under consideration. Bees most characteristically taken in regions of high humidity and low evaporation rate were shown to die sooner, under conditions of high temperature and low humidity, than did bees found to frequent a more dry region of low relative humidity. Bees that were considered as "general" or visiting all types of communities indiscriminately, in at least one series of data, indicated longer survival than either "moist" or "dry" adapted bees. It may be concluded that these "general" bees would prove most hardy, if averaged under all conditions of lethal character and compared with "moist" or "dry" adapted bees tested under the same sets of conditions. The question of supposedly "general" social bees being in reality "moist" is discussed later.

Experiments are needed to determine whether the so-called "oligoleges" of Robertson occurring in certain communities are apparently adapted to the environmental conditions, or seek the host flower and are unaffected by the physical factors. It is probable that the bees might be adapted to both the flowers and the physical characters, at least in some instances. If this were true, either adaptation might have preceded the other.

From the data, the conclusion must be reached that there are certain species of bees characteristic of certain plant communities. Other bees most certainly must be considered "general," in flower-visit distribution at least. Then any lists of the animals of a plant community should most certainly include numerous species of bees, some of them as casual visitors, others as visitors restricted either entirely or in part.

Comparison of survival of groups and isolated bees, of these various species of bees, indicates a possible difference in survival, between the social or semi-social bees and the non-social or solitary bees. The social or semi-social bee groups are shown to outlive the isolated bees. Data from the non-social bees are inconclusive, though suggestive, and further experimentation is necessary.

Consideration of these facts, in the light of the experiments with isolated bees only, suggests the possibility that social or semi-social bees are really adapted to moist conditions of high relative humidity and are moist, dry, or general in their flower-community visits due only to flower preference or abundance. This explanation has the advantage of solving the question of the longer group-survival by ascribing it to communal "effort" to block air flow, as well as to "soothing" effects of other members of the group in cutting down activity and metabolism and permitting an effective massing, thus invoking the surface-mass ratio.

Solitary bees, no matter how adapted to dry environments, may be adversely stimulated to activity by the presence of other bees.

The habit of the *Halictidae*, of blocking nest-gallery openings with their heads, would seem to give added evidence for the assumption that the majority of the species of this family of semi-social bees maintain high humidity in the nest.

Furthermore, this assumption, that there is adaptation to "moist" conditions among the *Halictidae*, would seem to explain the lack of correlation between apparent environmental adaptations and actual survival in experiments with the *Halictidae* (see particularly Tables XIII and XIV).

Further experiments should be undertaken. Live bees should be taken without a net, should be transported at once to the laboratory, and experiments should be made without delay. These experiments should most certainly be made with additional species of supposedly non-social or solitary bees. Toleration experiments using groups and isolated specimens of these species may bring to light other bees developing social habits and may confirm or correct the suggestions along that line advanced in this work.

VII. SUMMARY

1. A complete check-list for the bees of any locality possessing habitats of the variety of those in the Chicago area would require a considerable number of years to complete. It has been possible by extensive collecting, however, to prepare in two seasons a representative list undoubtedly including certain data concerning over half of the species to be expected within a seventy-five mile radius of Chicago. One hundred and sixty-nine species have been identified.

2. The similarity of the floras and bee faunas of the Carlinville and Chi-

chicago areas justifies making use of data accumulated by Robertson in the Carlinville area, which deal with relations between bees and flowers,—one of the closest of plant-animal relations.

3. Certain comparisons have been made of relations between flowers and bees predicted from Robertson's records with records accumulated in the Chicago area and they further justify using the Southern Illinois data.

4. It seems to be true that, though there is a frequent "preference" for some community or community type, bees are to be thought of as "following" the flowers and as being probably secondarily adapted to the communities which they are thus led to frequent. Only occasionally is it possible to indicate a bee as a visitor to only two or three communities. Yet it is quite feasible to present lists of bees to be expected in the various communities at the proper seasons if the collector makes sure to visit the community at all times of the blooming season.

5. Certain families of bees are shown to be more characteristic of a given community than of another. *Apidae*, *Bremidae* (*Bombidae*), and *Halictidae* are the most ubiquitous.

6. It has been possible to bring live bees into the laboratory and test their survival under varying conditions of temperature and humidity, in order to examine whether there is a correlation between survival and type of community most frequented. There is some indication that such correlation exists among certain bees. It was most definitely shown that bees visiting all kinds of communities are in general more hardy than bees restricted to dry or moist conditions. The smaller the bee, the less possibility of detecting physiological adaptation to moisture or dryness, if such adaptation exists.

7. Checking groups and isolated individuals of bees under experimental conditions indicated a general adaptation permitting social or semi-social bee groups to live longer than isolated individuals. No conclusive data have as yet been obtained for the non-social bees.

8. The data suggest a general adaptation of semi-social and social bees to moist conditions, their nesting habits permitting them to have such an adaptation and yet visit all types of communities. Non-social bees appear to be adapted to either moist or dry conditions, according to the communities in which they nest and which they frequent while collecting pollen and other substances.

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APPENDIX A

ROBERTSON'S REVISED LIST OF OLIGOLECTIC BEES

This list of oligoleges and their pollen flowers is modified from "Ecology," VII, 1926, originally incorrectly printed in "Ecology," VI, 1925. Of the 83 oligoleges in this list, the writer has collected specimens of 37 species, designated in each case by a single "c" following the species name. Of the 37 taken in the Chicago region, 19 species have been observed collecting pollen on the designated host or on one of the host group and are designated by "cc." There is some question concerning the validity of Robertson's *Melissodes boltoniae*. If it is a true species, the writer has specimens.

<i>Andrena arabis</i>	c....	Cruciferae
<i>erythrogastra</i>		Salix
<i>illinoensis</i>		Salix
<i>macoupinensis</i>		Salix
<i>nigrae</i>		Salix
<i>nothoscordi</i>		Nothoscordum striatum
<i>nubecula</i>	c....	Astereae
<i>salicacea</i>		Salix
<i>salicis</i>		Salix
<i>salictaria</i>	cc....	Salix
<i>Iomelissa violae</i>		Viola
<i>Opandrena ziziae</i>	c....	Umbelliferae, zizioid
<i>Parandrena andrenoides</i>	cc....	Salix
<i>Pterandrena aliciae</i>	cc....	Heliantheae
<i>asteris</i>		Astereae
<i>helianthi</i>	cc....	Astereae, Heliantheae
<i>krigiana</i>	c....	Krigia amplexicaulis
<i>pulchella</i>	c....	Heliantheae
<i>rudbeckiae</i>	cc....	Heliantheae
<i>solidaginis</i>	cc....	Astereae
<i>Ptilandrena erigeniae</i>	cc....	Claytonia virginica
<i>g. maculati</i>	c....	Geranium maculatum
<i>polemonii</i>	c....	Polemonium reptans
<i>Trachandrena mariae</i>	cc....	Salix
<i>spiraeanae</i>		Aruncus sylvester
<i>Colletes aestivalis</i>		Heuchera hispida
<i>albescens</i>		Petalostemum purpureum
<i>americanus</i>	cc....	Astereae, Heliantheae
<i>armatus</i>	cc....	Asterae
<i>brevicornis</i>		Specularia perfoliata
<i>compactus</i>	cc....	Astereae, Heliantheae, Helenieae

<i>latitarsis</i>	c....	Physalis
<i>robertsonii</i>		Petalostemum purpureum
<i>willistoni</i>	c....	Physalis
<i>Halictoides marginatus</i>	cc....	Helianthus
<i>Chloralictus nymphaearum</i>		Nymphaeaceae
<i>Macropis steironematis</i>		Steironema
<i>Anthemurgus passiflorae</i>		Passiflora lutea
<i>Calliopsis coloradensis</i>		Heliantheae, Astereae
<i>Perdita octomaculata</i>		Astereae, Heliantheae
<i>Perditella boltoniae</i>		Boltonia asteroides
<i>Pseudopanurgus albitarsis</i>	cc....	Heliantheae
<i>asteris</i>		Astereae, Heliantheae
<i>compositarum</i>	c....	Astereae
<i>labrosiformis</i>		Heliantheae
<i>labrosus</i>	c....	Heliantheae
<i>rudbeckiae</i>		Heliantheae
<i>rugosus</i>		Heliantheae
<i>solidaginis</i>		Astereae, Heliantheae
<i>Verbenapis verbenae</i>		Verbena
<i>Zaperdita maura</i>		Physalis
<i>Amegilla walshii</i>	c....	Cassia chamaecrista
<i>Emphor bombiformis</i>		Hibiscus
<i>Melitoma taurea</i>		Ipomoea
<i>Anthedon compta</i>		Oenothera biennis
<i>Cemolobus ipomoeae</i>	(ol.?)	Ipomoea pandurata
<i>Epimelissodes atripes</i>		Cassia chamaecrista
<i>illinoensis</i>		Heliantheae
<i>Melissodes agilis</i>	cc....	Astereae, Heliantheae
<i>asteris</i>		Astereae
<i>autumnalis</i>		Astereae, Heliantheae
<i>boltoniae</i>	c(?)	Astereae, Heliantheae, Helenieae, Cichorieae
<i>cnici</i>	cc....	Cirsium
<i>coloradensis</i>	cc....	Heliantheae, Cynarieae
<i>coreopsis</i>		Coreopsis palmata
<i>simillima</i>	cc....	Astereae, Helenieae
<i>trinodis</i>	cc....	Astereae, Heliantheae, Helenieae
<i>vernoniae</i>		Vernonia fasciculata
<i>vernioniana</i>	cc....	Vernonia fasciculata
<i>Peponapis pruinosa</i>		Cucurbita pepo
<i>Tetralonia robertsonii</i>		Papilionaceae
<i>Xenoglossa strenua</i>		Cucurbita pepo
<i>Anthidium psoraleae</i>		Papilionaceae
<i>Ashmeadiella buconis</i>		Astereae, Heliantheae
<i>Gnathosmia georgica</i>		Astereae, Heliantheae, Cichorieae
<i>Megachile generosa</i>	c....	Leguminosae
<i>sexdentata</i>		Heliantheae, Astereae
<i>strophostylis</i>		Strophostyles helvola
<i>Oligotropus campanulae</i>	c....	Campanula americana
<i>Sarogaster georgica</i>		Papilionaceae

Sayapis pollicaris	.....	Heliantheae
pugnata	cc.....	Heliantheae, Cynarieae
sayi	c.....	Heliantheae, Cynarieae, Eupatorieae

APPENDIX B

PLANT "ASSOCIATIONS" OR COMMUNITIES OF THE CHICAGO REGION

*Section A. Fuller's Associations.*¹—The roman numerals, or roman numerals followed by arabic numerals represent associations designated in Fuller (1925). The first column of arabic figures is used to designate the same associations but is used with flowers which do not appear in Fuller's list, but have either been stated by him to be found in the association designated, or have been placed there by reference to the description of the habitat of the flower, as given by Pepon (1927).

I. The Sand Dune and Upland Associations

1. I-1 The Beach Association
2. I-2 The Fore-dune Associations
3. I-3 The Cottonwood Association
4. I-4 The Pine Dune Association
5. I-5 The Black Oak Association
6. I-6 The Mesophytic Oak Forest Association
7. I-7 The Climax Mesophytic Forest
8. I-8 Sandy Swamp Associations

II. The Prairie Associations

9. II-1 Low Prairie
10. II-2 High Prairie

III. Aquatic Associations

11. III-1 Submerged Aquatics
12. III-2 Floating-leaved Aquatics
13. III-3 Emergent Aquatics
14. III-4 Reed Swamp Associations
15. III-5 Sedge Swamp Associations

IV. The Peat Bog Associations

16. IV-1 The Sedge Association
17. IV-2 The Xerophytic Shrub Association
18. IV-3 The Tamarack Association
19. IV-4 The Pine Birch Forest Association

20. V. The Rock Ravine Associations
21. VI. The River Cliff Associations
22. VII. The Flood-Plain Associations
23. VIII. The Lake Cliff Associations

¹Here Fuller's terminology has been followed, despite the fact that more recent terminology might break the associations up into associes and other more specialized groups. Elsewhere in this work these associations have been referred to as communities.

Section B. Man-dominated and other communities.—These communities are made up from designations given verbally by Fuller and are applied only to plants from Robertson (1928), which are not listed in Fuller (1928) as being characteristic of natural communities in the Chicago region. These communities do not appear elsewhere in the data but are given as references for future collecting.

24. Hillsides
25. Dry grasslands
26. Moist grasslands
27. Sandy soil
28. Ditches
29. Thickets
30. Pioneer
31. Burned clearings
32. Open dry situations
33. Railroad embankments
34. Ruderal
35. Old fields, old pastures, waste places
36. Orchards and fields
37. Meadow weed
38. Forest weed
39. Garden weed
40. Dooryard, barnyard weed
41. Weed
42. Introduced
43. Cultivated
44. Escaped cultivation
45. Cosmopolitan
46. Parasite
47. Existence doubted, very rare, old record, etc.

